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BRANCH MEETINGS

The following meetings have been announced.

Eastern—Lord Baltimore Hotel, Baltimore, Maryland
November 24 and 25, 1952
Southwestern—Hotel Galvez, Galveston, Texas
February 26 and 27, 1953
North Central States—St. Louis
March 19 and 20, 1953
Cotton States—Hotel Jung, New Orleans, Louisiana
February 9–11, 1953
Pacific—Sun Valley, Idaho
June, 1953

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Effects of Weathering and Commercial Dehydration upon Residues of Aldrin, Chlordane, and Toxaphene Applied to Alfalfa[1]

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In an earlier paper, Stansbury & Dahm (1951) have reported a study of the effect of commercial dehydration upon residues of aldrin, chlordane, parathion, and toxaphene applied to alfalfa at slightly greater dosages than are normally required for most insect control purposes. This initial experiment revealed that significant residue losses of all four insecticides occurred as the result of the dehydration process. Since dehydrated alfalfa not only is an important constituent in mixed feeds but also is used as a source of extraction for various products, it seemed advisable to compare the combined effects of weathering and commercial dehydration upon residues of three of the four insecticides used in the earlier study. In the case of parathion, in our laboratory analyses of its residues on alfalfa have indicated that insufficient residues for analytical purposes are present at the end of approximately three weeks weathering and hence it was omitted from this experiment. All the insecticides used in these studies have been employed to control several of the more destructive insects attacking alfalfa.

MATERIALS AND METHODS.—The three insecticides were all used in the form of emulsifiable concentrate formulations and were applied at the following rates per acre: aldrin, 2 ounces or 0.125 of a pound; chlordane, 1.0 pound; and toxaphene, 1.5 pounds. These insecticides were applied with a compressed air sprayer[3] provided with cross-mix agitation and operated at a pressure of 30 pounds per square inch. This sprayer was used for the first time in this experiment and its delivery-rate was calibrated before spraying. Approximately 20 gallons of water were used to apply the appropriate quantities of each of the three insecticides. During the application of the insecticides, the presence of a welding slag material in the tank caused frequent clogging of the coarse and fine strainer screens. This made it necessary to go over each experimental plot as many as two or three times in order to empty the tank of its contents.

The insecticides were applied to a 14- to 20-inch stand of fourth-cutting alfalfa in a 16-acre field. Six one-acre plots were laid out at one end of the field so that a one-acre plot which was not treated with insecticide was adjacent to each of the three treated plots. This arrangement reduced the danger of contamination from insecticides both at the time of application and at the time of cutting and harvesting. No other insecticide had been applied to the alfalfa in this field this year.

There was an elapsed time of 18 days between the application of the three insecticides and the cutting and dehydration of the alfalfa. The average maximum temperature during this period was 79° F. and the average minimum temperature was 52° F. The total precipitation recorded at Manhattan, Kansas during the

[1] Contribution No. 592, Department of Entomology. This work was aided by funds from Kansas Agricultural Experiment Station Project No. 323 (Hatch) and Julius Hyman & Co., Denver, Colorado. Presented as a paper at the Sixth Annual Conference, North Central States Branch, American Association of Economic Entomologists, Toledo, Ohio, March 22, 1951.

[2] Acknowledgements are gratefully made to Yao Hsiung, John L. Joy, Maurice E. Lamb, Ralph N. Massey, and Joe E. Pankaskie who, as students at Kansas State College, helped carry out this experiment; to A. A. Danish, N. H. Koenig, and Y. P. Sun of Julius Hyman & Co., Denver, Colorado, who provided the residue data; and to Richard Brown, operator of the Eureka Lake Alfalfa Mill Co., Route 1, Manhattan, Kansas, who provided the alfalfa fields and facilities of his dehydrator for these experiments.

[3] Essick air-power weed and pest control sprayer, model 920RT, Essick Manufacturing Company, Los Angeles, California.

experimental period was 0.09 inches. There was no heavy precipitation at the alfalfa field located approximately 4.5 miles west of the city during the experimental period, and therefore a value of approximately 0.1 inch of precipitation, or less, probably can be assumed for the alfalfa field area.

Except for minor differences noted below, the procedures of cutting, chopping, and dehydrating alfalfa, including the flow of the alfalfa through the commercial dehydrator, used in this experiment have been described previously (Stansbury & Dahm 1951). Three trucks and two cutter units were used to cut the insecticide-treated plots. All the alfalfa from each treated plot was hauled in one load to the dehydrator where it was dumped upon the empty automatic conveyor belt. The loads of alfalfa from the three treated plots were run through the dehydrator in consecutive order, sufficient time being allowed between loads for the dehydrator to empty. This was apparently a safe procedure because the flow of alfalfa through the dehydrator was accomplished with no lodging of particles, due to the strong air stream which carried the chopped alfalfa. The operating temperature of the dehydrator ranged from 900 to 950° F. while the alfalfa was being processed. Alfalfa from the untreated portion of the field was run through the dehydrator after the treated samples.

Four types of samples were collected during the experiment. The first series of field samples (I in Table 1) were collected immediately after the insecticide sprays were applied to the alfalfa. Four samples were collected from each of the treated plots; each sample consisted of approximately 15 subsamples totaling approximately 10 pounds of wet-weight alfalfa, gathered from all parts of each one-acre plot. Four samples were gathered in a similar manner at the same time from the untreated portion of the field.

A second series of field samples (II in Table 1) were gathered in a manner similar to that used for the first series of field samples 18 days after applying the insecticides and just prior to cutting the alfalfa. Additional samples from the untreated alfalfa were gathered at the same time.

A third series of samples (III in Table 1) were gathered from the loads of chopped treated and untreated alfalfa as they were lying on the conveyor belt at the dehydrator. Again four samples, each weighing about 10 pounds and consisting of approximately 15 subsamples, were taken from various parts of the load by means of a pitch fork and rake.

The fourth and last series of samples (IV in Table 1) were collected for each experimental condition, corresponding to those listed above, on the outlet side of the dehydrator just before the dehydrated alfalfa entered a hammer mill. Four approximately 10-pound samples were taken at intervals while the alfalfa was passing through the dehydrator. Similar samples from the untreated alfalfa were gathered in the same manner.

All samples were extracted in the laboratory the same day they were collected. Each of the four large samples comprising each series of samples (I, II, III, and IV), consisting of many subsamples, was throughly mixed on a table top covered with clean brown wrapping paper, and a 200-gram sample apportioned for extraction from each of the four large samples comprising a series. The alfalfa from the two sets of field samples was cut into short lengths, e.g., approximately one inch, before mixing and selecting the 200-gram samples. The other two series of samples were in a chopped condition when gathered. Each sample was transferred to a jar with a capacity of approximately five quarts and 400 milliliters of benzene were added. Technical, purified benzene was used to extract the first series of field samples (I) and thiophene-free benzene was used to extract the remaining series of samples (II, III, and IV). Some of the details of the extraction procedure and the rotary extraction apparatus have been described previously (Stansbury & Dahm 1951).

All samples were extracted for approximately 1 hour, after which the benzene extracts were decanted through cheesecloth into amber glass, screw-capped bottles. A total of 77 extracted samples were prepared for analysis. The extra samples resulted from a number of standard samples prepared by pipetting known volumes of benzene solutions of the three insecticides over 200-gram samples of untreated alfalfa before extraction. These standard samples were prepared to determine the per cent recovery for each in-

Table 1.—A summary of the effects of weathering and commercial dehydration upon residues of aldrin, chlordane, and toxaphene applied to alfalfa.

Insecticide	Emulsifiable Concentrate Formulation	Rate of Application of Insecticide	Residues in Parts per Million (p,p.m.)							Decrease of Residue by Dehydration[a]
			I Immediately after Spraying		II 18 days after Spraying		III Before Dehydration		IV After Dehydration	
			Wet Wt.	Dry Wt.	Wet Wt.	Dry Wt.	Wet Wt.	Dry Wt.	Dry Wt.	
	%	lb./A.								
Aldrin	25	0.125	2	10	<0.1[b]		<0.1[b]		<0.1[b]	—[c]
Chlordane	74	0.1	12	60	3	10	2	7	1	86
Toxaphene	65	1.5	30	50	14	47	6	19	5	74

[a] Calculated from: $100 \cdot \left[\frac{\text{p.p.m. Sample Series III, dry wt.} - \text{p.p.m. Sample Series IV}}{\text{p.p.m. Sample Series III, dry wt.}}\right]$

[b] Although no aldrin could be detected by biological assay in any of these samples, the results are reported in terms of the sensitivity of the assay method.

[c] Insufficient residue remaining to calculate.

secticide. The moisture content of the various samples was determined by drying aliquots to constant weight in an electric oven.

An attempt was made to collect nozzle samples of the three insecticides at the time of application; but due to clogging of the strainer screens on the sprayer, as mentioned above, this plan did not materialize.

The following procedures were used in processing the benzene extracts of the alfalfa and conducting the residue analyses.[4]

Aldrin.—A 200-milliliter aliquot of the benzene extract, equivalent to 100 grams of alfalfa, was chromatographed at 2 drops per second through 15 grams of Attapulgus clay (lower layer) and 5 grams of magnesium oxide in a 2-centimeter tube. The adsorbent column was rinsed with 50 milliliters of benzene. The combined filtrate was placed in a flask fitted with a three-ball Schneider condenser and concentrated on the steam bath to about 10 milliliters. The residual liquid was diluted to exactly 25 milliliters with benzene, and replicate aliquots of this solution were bioassayed for aldrin content. The aliquots were allowed to evaporate in glass jars and house flies were exposed to the residues. The bioassay technique (Sun & Sun 1952) involved using 100 flies on each of six replicates and the mortality counts were made after 18 to 42 hours, depending on the time necessary to attain mortalities in the 30–80 per cent range. The aldrin content was determined by comparing the toxicity of the sample to flies with the toxicity of the corresponding untreated alfalfa extract prepared in the same way as the samples and containing known added amounts of aldrin.

Chlordane.—The chlordane residues on alfalfa were determined by a modification of the Davidow (1950) colorimetric method which is based on the production of a red color when chlordane is heated with a mixture of methanolic potassium hydroxide and diethanol amine. A slight modification of the Davidow procedure was required due to the presence of a great deal of waxy material in the benzene extracts of alfalfa. The benzene extracts were shaken with a mixture of adsorbents in the same manner as described by Davidow, and then the decolorized extracts were concentrated to near dryness. The concentrated materials solidified to a waxy consistency on cooling to room temperature. The waxy material was leached with three 10-milliliter portions of warm methanol (40° C.) and filtered; the filtrate was evaporatively concentrated to 5 milliliters, cooled to room temperature, and filtered again. This liquid was concentrated to near dryness and the residue analyzed for chlordane by the Davidow colorimetric procedure. The colors obtained with the treated samples were compared with standards made up from the untreated alfalfas containing known amounts of added chlordane and processed in the same manner as the treated

[4] Personal communication from A. A. Danish, Julius Hyman & Co., Denver, Colorado, dated March 14, 1951.

samples. The use of such standards was necessary because the color obtained with alfalfa extracts differed somewhat from that obtained with chlordane alone.

For determining residues of less than two parts per million, it is desirable to use aliquots representing 250 to 300 grams of alfalfa in carrying out the colorimetric analysis.

Toxaphene.—Toxaphene residues were determined by the total organic chlorine method wherein the alfalfa extracts were digested according to the sodium-isopropanol method used for determining DDT (Carter & Hubanks 1946). The chloride ion concentration following such digestion was determined by the usual Volhard procedure utilizing silver nitrate, potassium thiocyanate, and nitrobenzene.

In carrying out the analyses on the samples prepared by the above procedures the benzene extracts of two of the samples in each series usually were combined. Thus the analysis for each series was replicated at least twice.

RESULTS.—A summary of the data obtained in this experiment is shown in table 1. The residue data listed in table 1 are the average of at least two replicates for each series of samples rounded off to the nearest whole number.

The pooling of extracts in most cases resulted in two instead of four replications for a given insecticide and experimental condition. In a few cases all four extracts were analyzed individually. Although only the averages of the analyses are listed in table 1, the variation in analytical values seldom exceeded 25 per cent of the average value listed.

Of the several standard extracts submitted for determination of the insecticides recovered, in only one case was a value received. A recovery of 87 per cent was obtained from a field sample to which aldrin had been added at the rate of one part per million.

SUMMARY.—A single experiment was conducted to determine the effects of weathering and commercial dehydration upon residues of aldrin, chlordane, and toxaphene applied to alfalfa at rates generally recommended for insect control on this crop. Of the many factors involved which influence the amount of residue found on treated forage the following conditions were present in this experiment: Dosage rates of toxicant per acre were: aldrin, 2 ounces or 0.125 pound; chlordane, 1.0 pound; and toxaphene, 1.5 pounds. The insecticides were all applied with a commercially available compressed air sprayer to one-acre plots. Commercially available emulsifiable concentrates of the three insecticides were used.

The insecticides were applied to a 14- to 20-inch stand of fourth-cutting alfalfa. Less than 0.1 inch of precipitation fell during the 18-day experimental period of weathering. Details of the types of samples, harvesting conditions, sampling, and analyses are described.

Alfalfa samples gathered immediately after spraying the three insecticides at the dosages indicated above contained the following average residues: aldrin, 2 p.p.m.; chlordane, 12 p.p.m.; and toxaphene, 30 p.p.m. Samples gathered 18 days later contained the following average residues: aldrin, less than 0.1 p.p.m.; chlordane, 3 p.p.m.; and toxaphene, 14 p.p.m.

Samples taken from loads of cut and chopped alfalfa from the same plots just prior to being processed by a commercial alfalfa dehydrator contained the following average residues: aldrin, less than 0.1 p.p.m.; chlordane, 2 p.p.m.; and toxaphene, 6 p.p.m. Samples taken following dehydration contained the following residues: aldrin, less than 0.1 p.p.m.; chlordane, 1 p.p.m.; and toxaphene, 5 p.p.m.

All values are based upon the wet or "as gathered" weight of the samples. Corresponding values based upon the dry weight of the samples are also given. The three less than 0.1 p.p.m. values for aldrin are reported in terms of the least aldrin detectable by the assay method used.

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The Physical Fate of Parathion Applied to Citrus[1]

G. E. Carman,[2] F. A. Gunther,[3] R. C. Blinn,[4] and R. D. Garmus[5]

It has become increasingly apparent that the development of new insecticides for use on agricultural crops must involve a thorough accounting of the fate of the insecticidal residues or degradation products thereof in the environment. Presumably, the consumer products, the remaining plant tissues, the surrounding atmosphere and the soil medium all may be contaminated. Whether or not it is necessary to trace these moieties of insecticidal origin through any or all of these media and to establish their fate will depend on the pharmacological importance of the insecticide and its pertinent chemical and physical characteristics.

Within recent years a great deal of attention has been given to the matter of insecticidal residues on and in treated commodities and to the factor of insecticide accumulation or degradation in the soil. Little has been done to establish the source, magnitude, and duration of atmospheric contaminations or to determine the stepwise and ultimate alteration or degradation of insecticidal molecules in plant tissues.

In developing the use of parathion on citrus to control California red scale, *Aonidiella aurantii* Mask., and certain other important economic pests it became apparent that because of the high dosages required, an initial limiting aspect of its use on citrus concerned the posttreatment fate of the material. This was particularly important in so far as hazards might be involved in the use of the treated commodity or in the exposure of man and animals to the contaminated environment.

The results of extensive studies undertaken to determine the distribution, magnitude, and persistence of parathion residues in citrus fruits have been published (Barnes *et al.* 1950, Carman *et al.* 1950, Stearns 1949). The interpretation of these results with regard to consumer hazard is dependent upon the adoption of official tolerance levels for parathion.

The potential, but somewhat more obscure, hazard from incidental or prolonged exposure in or near parathion-treated areas was suggested in part by the transitory nature of extra-cuticular and cuticular residues on citrus fruit (Gunther *et al.* 1950). Concurrently it was found that sub-cuticular residues decreased rapidly during a period of three to four weeks following application. In southern California, citrus tree surfaces are normally covered with dust and micro-debris. This condition coupled with the use of parathion formulated as wettable powders suggests that losses of parathion into the grove environment may in part be as air dispersions of contaminated particulate matter (Martin 1940). That the type of formulation may be important in this connection was shown in the present studies by preliminary bioassays with houseflies in which complete kills were recorded in or under the trees sprayed with parathion as a wettable powder, whereas somewhat lower mortalities occurred among flies stationed in or under the trees sprayed with liquid formulations containing parathion. The most hazardous exposures to parathion residues of this sort would result from mechanical dislodgement during posttreatment preoperations involving tillage, picking, pruning, and the like. Within limits these operations can be scheduled so as to avoid the necessity of exposing field workers during the immediate posttreatment period. For example, in citrus operations a 30-day safety period has been found sufficient although longer periods may be required on other crops, such as grapes.

It can also be reasonably conjectured that parathion may be present in or near a treated area in the vaporized or gaseous state. In table 1 typical vapor pressures of five insecticidal compounds are shown to illustrate the comparatively low vapor pressure of parathion. While the concentrations of parathion likely to be present in this state would be very low and their absorption largely restricted to inhalation, long and continuous exposures might

[1] Presented in part before the 121st National Meeting of the American Chemical Society, Milwaukee, Wisconsin, April 1, 1952.

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[4] Principal Laboratory Technician, Citrus Experiment Station.
[5] Senior Laboratory Technician, Citrus Experiment Station.

Table 1.—Comparison of vapor pressures of several insecticidal compounds.

Insecticidal Compound	Temperature °F.	Vapor Pressure μ	Reference
Naphthalene	68	64.5	Barker (1910)
	131	1290	Barker (1910)
Nicotine	77	20	Young & Nelson (1929)
	104	60	Young & Nelson (1929)
	142	620	Young & Nelson (1929)
p,p'-DDT	68	0.0002	Balson (1947)
	122	0.013	Balson (1947)
gamma-BHC	68	0.0094	Balson (1947)
	158	9.3	Balson (1947)
Parathion	68	0.04	Bright (1950)
	75	0.03	Williams (1951)
	130	0.66	Williams (1951)
	160	2.8	Williams (1951)

become significant. Ewart *et al.* (1951) observed a mortality of citricola scale, *Coccus pseudomagnoliarum* (Kuw.), on untreated trees adjacent to areas treated with parathion wettable powder and a decreasing effect on trees progressively remote from the treated area. Hoffman (1949) and others have called attention to the fumigant properties of parathion in closed (static) systems under controlled laboratory conditions. With human dwellings and animal shelters frequently located in or immediately adjacent to citrus groves it appeared highly desirable to determine the magnitude of air-borne parathion residues and the duration of this environmental contamination.

Several workers have reported on the measurement of air contaminations from parathion. Brown & Bush (1950) reported amounts ranging from 1 to 8 milligrams of parathion per 10 cubic meters in the air during various operations in an industrial formulating and packaging plant. Hirt & Gisclard (1951) described sampling equipment and analytical procedures useful in detecting parathion present as vapor, mist, or air-borne impregnated dust. They found minimum samples of 20 liters of air would be required to detect parathion as vapor in saturated atmospheres at 80° F. Much larger air samples would be required to detect parathion at concentrations of 0.1 microgram per liter or less. Working in a citrus grove during the immediate postapplication period and utilizing the general procedure outlined by Hirt & Gisclard *et al.* (1951) found from less than 0.002 to 0.005 p.p.m. of parathion in the air with the higher levels detected during the first 5 days after treatment. Test animals caged in the treated area showed no effects from exposure as measured by cholinesterase levels in the red blood cells and plasma or as evidenced by any gross pathology during autopsy of the sacrificed animals.

During the summer of 1950 air sampling studies undertaken by the American Cyanamid Company[6] in treated citrus groves indicated a range of from 0.001 to 0.07 p.p.m. of parathion 1 hour to 6 days after application.

In this report the apparatus and procedures used to sample the atmosphere surrounding parathion-treated plant surfaces and to recover and measure the parathion contained therein as contaminant are described. Both laboratory and field approaches have been utilized. Because of the nature of the problem it was necessary to determine the contamination in a dynamic airflow instead of that in a closed (static) system.

The laboratory investigations were designed to elucidate the factors controlling the re-issuance or vaporization of parathion existing as extra-cuticular or subcuticular residues of treated oranges and to determine the extent of other losses by metabolic degradation or by possible interaction with enzyme systems. In studies previously cited (Carman *et al.* 1950) parathion residues of Valencia oranges and Eureka lemons decreased 78 and 82 per cent, respectively, from initial levels during the first 17 days after treatment. With Valencia oranges treated at the same dosage, relatively low losses (12 per cent) were recorded during the period from 105 to 230 days after treatment.

In these studies analyses of the total parathion content of similarly treated fruit at the beginning of the laboratory test period and of the aerated fruit at the termination of the test were correlated recoveries of parathion deriving from surface losses. Bioassays with houseflies provided supplementary information. This initial investigation involved preliminary considerations of the factors of time, light, and type of deposit. More elaborate investigations are currently in progress to evaluate further these parameters as well as to consider the additional factor of temperature.

[6] Parathion vapor concentrations in the atmosphere of California groves during and after application. American Cyanamid Company, New York (T-112-1M-9-51).

The field studies were designed to determine the amounts of parathion likely to be present as atmospheric contaminant in citrus groves during the immediate post-treatment period and to correlate the influence of temperature, humidity, wind movement, and dosage of parathion per acre on the magnitude and duration of this contamination. Primary emphasis was placed upon the physical recovery and subsequent measurement of the air contaminant. Since preliminary studies had indicated the need for large air samples and since certain of these environmental factors could only be evaluated properly over an extended period, the field equipment was constructed to permit the sampling of relatively large volumes of air (2.5 liters per minute) and to permit a short interval direct reading of absorbed parathion. Bioassays with houseflies were made concurrently.

Limited studies were also undertaken to establish the sensitivity of the present equipment to a compound with higher vapor pressures at the temperatures encountered in these tests. Nicotine was selected for this purpose (Table 1).

MATERIALS AND METHODS.—The equipment used to collect parathion vapors liberated from treated oranges is shown schematically in figure 1. Parathion-free air at a constant 4 pounds of pressure was bled into the lower inlet of the incubator jar at 300 cubic centimeters per hour. The effluent air could either be passed through the glass fly cage or be routed directly to the absorber system.

All tests with houseflies involved 24-hour exposures of lots of 25 female houseflies each, three days old, to the effluent air stream. Moribund flies were included in the mortality counts.

The primary absorber consisted of a 2 by 10 centimeter cylindrical bubbler, of coarse porosity, immersed in sufficient benzene to give a minimum bubble path of 15 centimeters. The secondary absorber served to check the adequacy of the primary absorber, and its contents were always analyzed separately. The outlet of this absorber was vented to the hood. All stopcocks and joints were greased lightly with a silicone high-vacuum type lubricant, and the latter were positioned by means of strong springs. The results reported herein were accrued at room temperature, which varied from 60 to 80 F. Two of these units were employed in parallel.

In a typical run, as many weighed oranges (about 1400 grams) as possible were carefully placed in the clean incubator jar. Bruised fruits were rejected. Two-hundred milliliters of benzene was placed in the primary absorber and 30 milliliters in the secondary absorber. With the various stopcocks so placed as to permit the passage of air from the incubator jar through the absorbers, gentle suction was applied to the outlet of the secondary absorber until both bubblers functioned.[7]

The standard taper stopper was then clamped by means of springs into the incubator jar, and air at 4 pounds of pressure was bled into the system until the suction could be removed without stopping the bubblers. Air input was then adjusted to 30 cubic centimeters per hour, as measured by benzene displacement at the drain tube. At progressive intervals, 100 milliliters of the solution in the primary absorber was removed by pressure displacement through the drain tube, and replaced with 100 milliliters of fresh benzene. The withdrawn sample was analyzed for its parathion content by means of the Averell & Norris (1948) procedure.[8] Every other day 25 female houseflies, 3 days old, and a piece of wicking saturated with sugar solution were introduced into

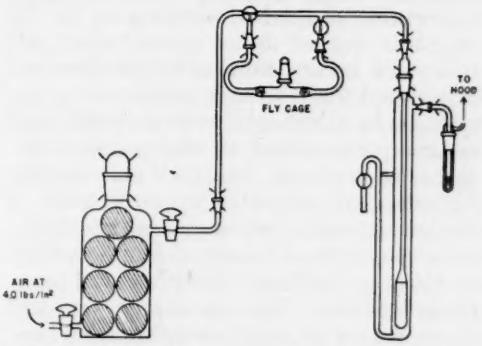

FIG. 1.—Schematic diagram of all-glass laboratory apparatus to collect parathion vapors liberated from treated oranges.

[7] Without the application of gentle suction, about 8 pounds of pressure was required to overcome the resistance of the two bubblers in series; this pressure frequently loosened a joint or stopcock. After being started with suction, however, 4 pounds of pressure maintained bubbling without difficulty.

[8] The simpler direct ultraviolet spectrometry of an ethanol solution (Hirt & Gisclard 1951) could not be used in these small scale incubation experiments because of the interferences of the effluvium from the flies and of some of the volatile constituents of oranges.

Table 2.—Parathion recoveries after aeration from Valencia and navel oranges treated in the field

Variety	Days After Treatment[2]	Days Aerated	Per Cent Wt. Loss	Mg.[1] Parathion/100 g. of Fruit			Per Cent Parathion Recovered from Fruit
				Initial[3]	Final	Absorbers	
Valencia	6 a	39	4.6	162	131	<10	81
	6 b	39	4.0	165	130	<10	79
Navel	3 a	15	2.2	631	469	<10	74
	3 b	15	2.0	521	337	<10	65
	1/6 a	62	10.1	1285	390	10	30
	1/6 c	62	9.1	0	0	0	—

[1] Mg. = micrograms.
[2] a = 1 quart of parathion 25 per cent emulsifiable concentrate 100 gallons.
b = 2 pounds of parathion 25 per cent wettable powder in 100 gallons.
c = untreated check.
[3] "Initial" here refers to residue at beginning of aeration period.

the glass fly cage, and the air stream was diverted across them for 24 hours. After a mortality count had been made, the fly cage was cleaned in hot concentrated sulfuric acid before another lot of flies was introduced and the cage reinserted in the system. At three-day intervals additional benzene was added to the primary absorber to replenish the small amount lost by evaporation. After approximately 3 weeks of continuous aeration, the fruits were removed and analyzed as described by Gunther & Blinn (1950) for total parathion content. The incubator jar and stopper were rinsed thoroughly with benzene, and these combined rinsings and the two absorber solutions were analyzed separately for parathion content.

AERATION OF PARATHION WETTABLE POWDER.—When 1 gram quantities of the thoroughly mixed 25 per cent wettable powder were spread in thin layers in shallow porcelain dishes in the incubator jars, there were only minor (5 and 6 per cent) losses in their parathion contents after 27 days. Parathion was not recovered from either absorber system nor were flies killed during 24-hour exposure periods in the air streams.

AERATION OF PARATHION-TREATED FRUIT.—Typical parathion recoveries from freshly treated Valencia and navel oranges are shown in table 2. Neither intense fluorescent illumination nor complete exclusion of illumination had any appreciable effects on the rates of parathion loss from the fruit. In these experiments also, there was no mortality of the flies exposed to the air streams.

DISCUSSION OF RESULTS.—A negligible quantity of parathion was lost from the aeration of the wettable powders. *In situ* parathion residues are lost from orange peel at a decreasing rate and approach a constant low value representing an approximate 22 per cent retention of the original residue load (Carman *et al.* 1950). This ultimate residue appears to reside in the rind oil, and persists for long periods of time. This nearly 80 per cent loss of identity of *in situ* parathion could result from three mechanisms: (1) re-issuance followed by volatilization or other physical displacement, (2) metabolic degradation, and (3) interaction with an enzyme system to afford a benzene insoluble (Gunther & Blinn 1950) adduct or other reaction product. The present report is concerned with mechanism (1) the closely related mechanisms (2) and (3) will be considered in detail in future reports.

It is apparent from the data in table 2 that the loss in weight of the fruit during aeration was proportional to the length of aeration. No attempt was made to presaturate the incoming air with water vapor; accordingly, final analytical values are corrected for this desiccation factor. Possible monolayer adsorption of parathion on the internal glass surfaces of the system would account for only negligible amounts of the losses indicated. The type of parathion formulation used did not greatly influence the apparent loss of compound during the aeration period. Losses were greater from fruit freshly treated than from fruit sampled longer periods after treatment.

When these investigations were initiated, reliable vapor pressure data for parathion were not available. However, calculations based upon the recent data of

Williams (1951) show that the maximum amount of parathion which could have been recovered from an absorber system in these laboratory experiments would have been 104 micrograms at 68° F. in 30 days at 300 cubic centimeters of air per hour. Consequently the colorimetric method for determining parathion was adequate for the present purpose.

FIELD INVESTIGATIONS: MATERIALS AND METHODS.—The apparatus used for these field investigations continuously sampled large volumes of air in treated groves and simultaneously indicated the amount of pesticide in the total air sample at any given time. The all-glass air sampler contained a 22-inch long absorber tube, with a 2 by 10 centimeter fritted glass cylindrical bubbler, of coarse porosity, series-connected to a glass circulating pump composed of two check valves and a 100 milliliter hypodermic syringe, a 95 per cent ethyl alcohol reservoir to maintain constant volume of absorbing solvent, a spray tower to trap and return any spray from the absorber, and a flexible ball-joint system to connect the circulating pump to the special measuring cell in the spectrophotometer, with return line to the absorber. It was not necessary to employ glass for parts of the system not in contact with the alcohol or its vapors. A rotometer (0 to 200 liters per hour) and a vacuum pump were accessory equipment. Details of the air sampling system are shown schematically in figure 2, while those of the all-glass flexible connection to the spectrophotometer are shown in the photograph in figure 3. A second, matched 10 centimeter cell filled with 95 per cent ethyl alcohol was used to balance the spectrophotometer before every reading.

The apparent presence or absence of the pesticide was established simultaneously in two ways; by degree of ultraviolet absorption at 274 millimicrons and by bioassay with houseflies. In addition, the accepted colorimetric method was applied to the terminal absorber solutions from the parathion tests. Equipment for the direct spectrophotometric method included a Beckman Model DU spectrophotometer with the previously mentioned 10 centimeter quartz-faced cylindrical cells in a special light-proof housing. Power for the vacuum pump and constant voltage for the hydrogen lamp

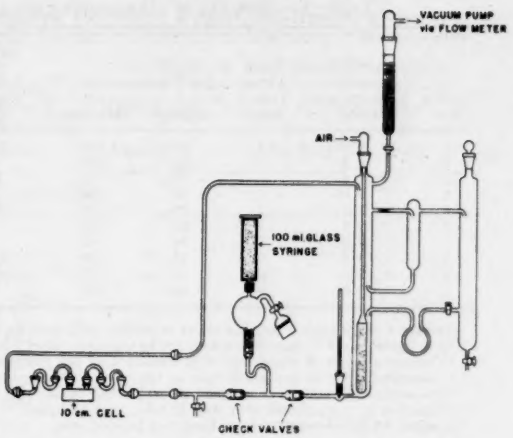

FIG. 2.—Schematic diagram of all-glass field apparatus to collect parathion vapors liberated in treated orange groves.

power unit were provided by a gasoline-powered 110 volt A.C. generator with voltage regulator. The spectrophotometer was shielded from direct sunlight at all times.

Bioassays were made by confining adult female houseflies during the sampling period either in 1-quart paper cartons as previously described or in the air stream of the intake line. Mortalities were observed during the course of the run and subsequently at the end of an additional 24-hour period. The fly cage units inserted in the air line consisted of 2 by 10 inch plastic tubes with threaded plastic caps through which 0.25 inch hose nipples were inserted. Fine mesh brass screen inserts were fitted inside the

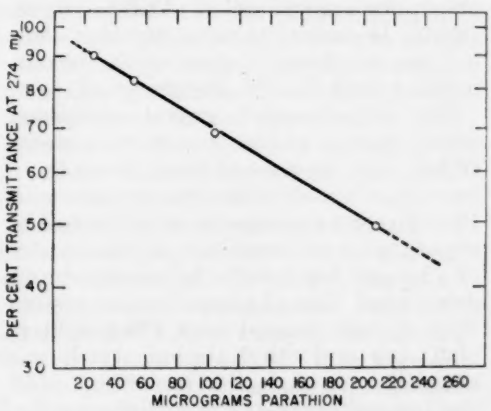

FIG. 3.—Calibration curve for parathion in field air sampling apparatus, added as a 0.005 per cent solution of molecularly distilled parathion in 95 per cent ethyl alcohol, at 274 millimicrons.

Table 3.—Results of air sampling studies in parathion-treated orange groves.

Grove No.	Actual Parathion (Pounds per Acre)	Days After Treatment	Air Temperature, °F.		Average Wind Velocity Feet per Hour	Per Cent Fly Mortality		Apparent Parathion (mg./M.³)	
			Average	(Maximum)		In Grove	Outside Grove	Ultraviolet[1]	Colorimetric[2]
1	8.0[3]	1	92	(95)	—	—	—	0.16±0.05	— —
2	9.6	1	68	(70)	924	85	0	0.13±0.03	— —
3	11.2	1	70	(75)	1460	100	0	0.13±0.04	— —
4	6.0[4]	1	88	(90)	480	5[5]	5	0.33±0.09	0.01 0.01
5	5.9	1	95	(99)	2030	90[6]	100[7]	0.20±0.07	0.03 —
6	6.0	1	85	(94)	178	—	—	0.17±0.08	0.02 <0.01
6	6.0	2	86	(93)	582	—	—	0.15±0.08	0.01 0.00
6	6.0	4	95	(99)	588	—	—	0.17±0.09	0.01 0.00
6	6.0	9	95	(101)	3496	—	—	0.17±0.08	0.04 0.00
7	0.0	—	94	(98)	—	0	0	0.17±0.03	0.00 0.00

[1] Averaged value from 6 to consecutive sampling periods of 30 minutes each.
[2] First figure refers to apparent parathion in absorber, second to apparent parathion in alcohol extract of the fritted filter.
[3] In combination with compound 88R used as a 25 per cent emulsifiable preparation at the rate of 20 quarts per acre.
[4] In combination with zinc oxide used at the rate of 15 pounds per acre.
[5] Flies confined in stream of sampled air which had passed through the fritted filter.
[6] Other flies in cages placed near tops of trees were all killed.
[7] Located 40 feet downwind from border of treated area.

threaded caps on both ends to retain the flies. A 10-centimeter fritted filter of coarse porosity was attached to the inlet vent of one of these tubes. Temperature, humidity and air movements in the immediate vicinity of the equipment were determined by accepted means.

The colorimetric parathion determinations were based upon the Wilson *et al.* (1951) micro-adaptation of the Averell & Norris method (1948) with the following modifications: to 100 milliliters of the alcoholic solution from the absorber were added 10 milliliters of concentrated hydrochloric acid and 0.2 gram of zinc dust; after this mixture had been refluxed for one hour, the alcohol was evaporated on the steam bath to 10 milliliters, then filtered. The procedure of Wilson was followed thereafter. The nicotine determinations were based upon the ultraviolet absorption procedure of Willets *et al.* (1950). However, 95 per cent ethyl alcohol was employed instead of the recommended 0.05 N acid absorbing solution.

The experimental groves contained evenly spaced mature orange trees about 20 feet high. In most of these groves there were approximately 90 trees per acre with 10 to 20 acres per experimental block. The apparatus was assembled at the center of a treated block with the generator unit down wind. The all-glass absorber system (Fig. 2) was charged with 175 milliliters of 95 per cent ethyl alcohol, which was circulated through the apparatus until the transmittancy at 274 millimicrons became constant, thus indicating that all the alcohol solution in the apparatus was of uniform composition. When flies were confined in the air inlet line, two plastic tubes containing 20 female flies each were connected to the apparatus in the following sequence: absorber inlet to first plastic tube to fritted filter to second plastic tube to atmosphere. Airflow through the absorber was adjusted to 150 liters per hour by means of a bleeder stopcock on the vacuum pump. At intervals of either 15 or 30 minutes the alcohol was circulated until its transmittancy again became constant. This transmittancy and the temperature of the alcohol solution, air temperature, relative humidity, wind velocity and direction, and condition of the flies were then recorded. This procedure was followed for the duration of the test. At the conclusion of the test the spectrum of the absorbing solution was traced from 230 to 300 millimicrons. This alcohol solution was then withdrawn for subsequent colorimetric determination of parathion content.

PARATHION IN TREATED GROVES.—Typical data obtained as the result of air sampling studies in treated orange groves are shown in table 3. The parathion applications were made by commercial pest control operators using conventional high pressure spray equipment.

In individual groves the total volume of air sampled during an operation ranged from 450 to 750 liters, dependent upon the number of 30-minute sampling periods. The relative humidity within the treated groves, which was determined at the end of each consecutive 30-minute sampling period, varied from 26 to 70 per cent.

Detailed data from a typical sequential

Table 4.—Detailed data from sequential air sampling studies in a parathion-treated grove.

Sampling Interval	Air Temperature, °F.	Relative Humidity (Per Cent)	Wind Velocity (Feet per Hour)	Micrograms Apparent Parathion		
				Ultraviolet	Colorimetric	
				Absorber	Absorber	Filter
1 Day After Application						
0 (10:55 A.M.)	75	59	—	0	0	0
1	77	60	260	9		
2	79	56	100	28		
3	82	55	60	9		
4	82	50	80	14		
5	88	49	360	13		
6	87	45	20	14		
7	91	45	140	11		
8	93	37	300	12		
9 (3:25 P.M.)	94	36	280	17	10	2
9 Days After Application						
0 (11:10 A.M.)	85	64	—	0	0	0
1	85	42	40	15		
2	91	36	364	20		
3	95	34	2260	9		
4	98	27	1900	8		
5	99	26	5600	25		0
6	101	31	6300	18		
7	99	30	6500	8		
8	99	28	5000	9		
9 (3:40 P.M.)	100	29	—	8	24	

air sampling study in a parathion treated orange grove are collated in table 4 in order to demonstrate the degree of variability encountered for the several factors under consideration.

NICOTINE IN TREATED GROVES.—In table 5 are reproduced typical recoveries of nicotine from air samples collected in an orange grove treated on two different occasions with two quarts of 40 per cent nicotine sulfate and two pounds of calcium caseinate spreader per 100 gallons of finished spray using air-blast spray equipment of the Master Fan type. Background apparent nicotine values were established for this grove each time during the hour preceding the application. During the treatment period the sampling apparatus was left in position but protected from the spray with a plastic covering. In September and in December the air samples were collected immediately after application so as to obtain an indication of the effect of air temperature upon this more volatile pesticide.

Table 5.—Detailed data from sequential air sampling studies in a nicotine-treated orange grove.

Sampling Interval	Air Temperature, °F.	Relative Humidity (Per Cent)	Apparent Nicotine[1] (mg./M$_3$)
September			
1 (11:00 A.M.)	88	47	1.07
2 (11:15 A.M.)	90	42	0.06
3 (11:45 A.M.)	93	28	0.02
4 (12:15 P.M.)	97	22	0.40
5 (12:45 P.M.)	99	20	0.00
December			
1 (12:50 P.M.)	61	34	0.35
2 (1:05 P.M.)	58	—	0.22
3 (1:20 P.M.)	62	31	0.12
4 (1:35 P.M.)	62	—	0.12
5 (1:50 P.M.)	63	31	0.07
6 (2:05 P.M.)	62	—	0.11

[1] Compensated for background values which averaged 0.40 milligram per cubic meter in September and 0.16 milligram per cubic meter in December.

DISCUSSION OF RESULTS.—Because of the sensitivity gain from the long light path of the special cells used in the spectrophotometer, unusual care was required to eliminate as many of the sources of interference as possible. These were alcohol-soluble contaminants from the apparatus itself as well as contaminants encountered in the sampled air. As mentioned, those portions of the apparatus in contact with the alcohol or with alcohol

Table 6.—Spectral interferences at 274 millimicrons of ethyl alcohol extracts of various types of tubing.

TUBING	TRANSMITTANCY AT 274 mμ
Gum rubber	60
Neoprene[1]	2
Polyvinyl chloride	2
Saran[1]	2
Silicone rubber	46
Teflon[1]	97
Tygon[1]	2
Solvent only	100

[1] Registered trade name.

vapors were constructed entirely of glass so as to minimize this source of interference. A number of commercially available types of flexible tubing were examined for interference in their alcohol extracts at 274 millimicrons. The results are shown in table 6. In these tests, 20 grams of the 0.25 inch O.D. tubing was cut into 0.125 inch lengths and shaken with 95 per cent ethyl alcohol for 6 hours. Kelef,[9] Nylon,[9] and Teflon[9] tubing were not sufficiently flexible for consideration, especially as components of the adjustable cell arrangement. The gum rubber, Saran,[9] Tygon,[9] and Neoprene[9] extracts possessed the sharp absorption maxima and minima characteristic of pure compounds, but the plasticizers or other additives responsible for these spectra could not be quantitatively leached from the tubing even after prolonged Soxhlet extraction. The silicone high-vacuum type lubricant used for stopcocks and all joints did not interfere since there was no significant change in transmittancy at 274 millimicrons of the alcohol after being shaken 20 hours with excess lubricant.

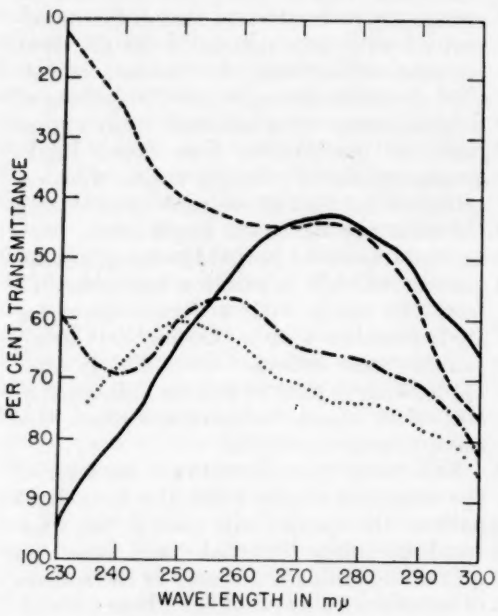

FIG. 4.—Typical transmittancy-wave length curves in 95 per cent ethyl alcohol for molecularly distilled parathion(——); nicotine as absorbed from grove air(- - - -); grove air background (———); and grove air background combined with the contribution from housefly effluvium (———).

In order to establish the response of the air sampling apparatus to parathion, the data underlying figure 4 were obtained. From this figure it is apparent that the response of the apparatus is in accord with Beers law over the range utilized. For practical purposes it is also apparent that responses below 26 micrograms of parathion may be assumed to obey this same linear relationship. In actual practice it has been found that the limit of interpretation of this linear relationship, and thus of the sensitivity of the apparatus, occurs with transmittance increments of approximately 1.5 per cent, or 4 micrograms of parathion, in the absence of quantitatively unevaluated background or other interferences.

Possible major interfering contaminants in the sampled air included exhaust fumes from internal combustion engines, other unsaturated organic substances from industrial sources, volatile oils from trees and other herbage, moisture and volatile decomposition products of para-

Table 7.—Contributions of apparent parathion from various background sources of air.

SOURCE OF AIR	APPARENT PARATHION (mg./M.[3])
From ocean[1]	0.07±0.03
Mountain top[2]	0.12±0.04
From untreated grove[3]	0.17±0.03
From treated grove[4]	0.17±0.08
From ocean[1] plus fly effluvium	0.15±0.03
From treated grove[4] plus fly effluvium	0.33±0.09

[1] From end of pier at Scripps Institution of Oceanography, La Jolla, California.
[2] Box Springs Mountain, approximately 2500 feet above city of Riverside.
[3] This grove had never been treated with pesticide materials during its entire existence.
[4] One day after application.

[9] Registered trade name.

Table 8.—Effect on transmittancy at 274 millimicrons of dilution of alcohol absorbing solution with water.

ALCOHOL CONCENTRATE (PER CENT)	AVERAGE INCREASE IN TRANSMITTANCY AT 274 mμ
95[1]	0
90	7
85	14
80	19

[1] Primary standard in the present investigation.

thion itself (*i.e.*, fragments retaining the benzene ring). Neither carbon dioxide nor carbon monoxide would be expected to interfere in that portion of the spectral region under examination.

Air-borne volatile oils in a citrus grove would include small quantities of methyl anthranilate and a variety of terpenoid structures. Many of these substances possess appreciable absorption at 274 millimicrons, although methyl anthranilate[10] in 95 per cent ethyl alcohol possesses an absorption minimum in the 270 to 276 millimicron region, with one maximum at 248 millimicrons and another beyond 320 millimicrons.

The difficulty of studying most of these possible contaminants in isolation led to the attempt to evaluate them by type, with the representative results shown in table 7. From these data it is possible to estimate the magnitude of the apparent parathion background (interference) contributed by certain major factors encountered in field operations.

In general, water is more transparent to ultraviolet radiation than is ethyl alcohol. Because of variable moisture content of air sampled in the field, it would be expected that the ethyl alcohol absorbing solution would vary accordingly in degree of dilution from condensed atmospheric moisture as well as from evaporative concentration. As shown in table 8, the presence of appreciable amounts of moisture in the air requires compensation in the interpretation of results.

Table 9.—Influence of temperature of dilute alcoholic solution of parathion upon transmittancy, at 274 millimicrons, at 30-minute intervals with no air circulation (see Figure 2).

SOLUTION TEMPERATURE, °F.	TRANSMITTANCY AT 274 mμ
80	95.0
99	95.0
100	95.0
102	95.0

That the temperature of the solution under spectral examination can influence the shape of the spectrogram is well established (Mellon 1950). In the present investigation it was found that the increased evaporative cooling of the absorbing solution largely balanced the high air temperatures experienced in the field. In addition, the data in table 9 demonstrate that temperature effects upon the system employed herein were minimal.

In figure 4 are reproduced typical transmittancy-wave length curves in 95 per cent ethyl alcohol as obtained with the present apparatus for molecularly distilled parathion (0.0002 per cent solution), nicotine as absorbed from grove air, grove air background, and grove air background combined with the contribution from housefly effluvium. The curves from the absorbing solutions from both parathion-treated and untreated groves were indistinguishable, whereas the presence of nicotine in grove air resulted in a pronounced hypsochromic effect on the resulting spectra. The curve demonstrating the background contribution from the housefly effluvium was obtained in the usual manner by drawing 150 liters of air per hour over 40 houseflies for 4 hours.

Table 10.—Summary of analytical results to demonstrate absence of parathion vapor from treated grove environment.

DAYS AFTER TREATMENT[1]	APPARENT PARATHION (mg./M.[3])
Before	0.17±0.03
1	0.17±0.08
2	0.15±0.08
4	0.17±0.09
9	0.17±0.08

[1] Six pounds of actual parathion per acre.

In table 10 are shown typical, summarized analytical results to demonstrate that parathion does not occur in the vapor or gaseous state in treated groves in amounts within the detectable range of this sensitive method. The combination of both ultraviolet and colorimetric

[10] Repeatedly recrystallized as the hydrochloride, then regenerated; concentration 1.25×10^{-4} molar. In contrast, 4.35×10^{-5} molar parathion in 95 per cent ethyl alcohol exhibits maximum absorption in the 273 to 275 millimicron region.

methods indicated that there was never more than 0.05 milligram of parathion vapor per cubic meter of grove air many of the nine treated groves tested. Supplementary housefly bioassays and colorimetric analyses of the extracts from the fritted funnel further demonstrated that particulate matter containing parathion may exist in small amounts in the atmosphere of treated groves.

GENERAL DISCUSSION.—As previously stated, the maximum amount of parathion which could theoretically have been released to the absorber system in the laboratory experiments was 104 micrograms in a typical run. Although the sensitivity of this technique is primarily that of the colorimetric method utilized and amounts to about 10 micrograms of parathion per analytical aliquot[11] under good conditions, it could be further limited by (1) adsorption of liberated parathion onto the internal glass surfaces, (2) absorption by the silicone lubricant used, and (3) absorption by the houseflies in the emergent air stream. Entrainment or other escape from the absorber system is hardly possible with the amounts of parathion theoretically anticipated. Assuming monolayer adsorption, the total glass surface (1) exposed to the vapor could account for only 3 to 4 micrograms of parathion. Although absorption by the silicone lubricant (2) was not evaluated, benzene washings from the incubator jar, including the benzene extracts of the lubricated large ground surfaces of the neck opening and stopper as well as those of the two stopcocks involved, did not exhibit more than traces (*ca.* 4 micrograms, which is less than experimental analytical error) of parathion. Adsorption by the houseflies (3) probably did not occur to any appreciable extent as indicated by the facts that Metcalf & March (1949) have shown that 0.02 microgram of parathion per fly as topical application will kill 50 per cent of the exposed flies in 24 hours, and that in these tests flies were never killed during any of the aeration experiments even though slight amounts of parathion were detected in the absorbing system (Table 2). It may be concluded, therefore, that the present technique is capable of demonstrating 10-microgram quantities of parathion in the air stream. Untreated samples of oranges did not release to the air stream demonstrable quantities of substances that would interfere with the colorimetric method. The sensitivity and reproducibility of the technique for determining total parathion in oranges have been fully discussed elsewhere (Gunther & Blinn 1950).

Sensitivity of this order of magnitude cannot be assumed for the field technique herein described. The ultraviolet method for determining parathion in the absence of interfering materials is functionally capable of detecting 9 microgram quantities of the pesticide contained in a 50-millimeter cell (Hirt & Gisclard 1951). The present apparatus, which incorporated a 10-centimeter cell, responded to as little as 4 micrograms of introduced parathion (Fig. 4). As may be seen from the summarized data in table 7, the background interference introduced into the field apparatus from a mature grove that has never been treated with any pesticidal materials amounted to 0.17 ± 0.03 milligram of apparent parathion per cubic meter of sampled air. Expressed in other units, this background interference[12] amounts to 85 ± 15 micrograms of apparent parathion per 500 liters of sampled air, or 0.15 ± 0.03 p.p.m., at 86° F. This order of sensitivity is considerably less than that indicated by other investigators who sampled air from parathion-treated citrus groves (Stearns *et al.* 1951 and footnote 6).

All housefly bioassay data reported herein are considered to be supplemental in nature and have only qualitative significance in the interpretations of amounts of apparent or real parathion encountered.

SUMMARY.—Two supplementary types of apparatus have been devised and utilized in laboratory and field studies to recover parathion in air as it might be released from surfaces of field-treated orange trees, either as parathion-contaminated particulate matter or in the vapor or gaseous state. Both types of apparatus are described in detail, and are evaluated as to limitations and utility.

In the laboratory, *in situ* losses of parathion from treated oranges occurred by

[11] Averell & Norris (1948) state that 20 micrograms can be determined in a photelometer, although their standard curve indicates an 86 to 87 per cent transmittance for a 20-microgram quantity of parathion. Gunther & Blinn (1950) found that with the same procedure as little as 10 micrograms afforded readable transmittance values of from 92 to 94 per cent in a spectrophotometer.

[12] Exhaust fumes from the gasoline-powered generator were carefully excluded.

some mechanism other than re-issuance to the surface followed by volatilization or other physical displacement.

In the field, parathion is not released to the grove atmosphere in the vapor or gaseous state in amounts detectable by the method utilized. Certain background interferences that were measured were found to be significantly limiting in the interpretations of the amounts of airborne parathion within the grove environment.

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The second annual meeting of the Entomological Society of Canada and the first of the Entomological Society of Quebec will be held at Laval University, Quebec, October 29, 30 and 31, 1952.

Hessian Fly Resistance of Ponca Wheat[1]

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For more than 25 years the incorporation of hessian fly, *Phytophaga destructor*, resistance into commercial hard red winter wheat has been one of the objectives of the wheat improvement and insect control programs of the Kansas Agricultural Experiment Station. These projects have been furthered by the release to Kansas farmers of Kawvale wheat in 1931 and Pawnee wheat in 1943. Pawnee derived its fly resistance from Kawvale. It became the leading variety in acreage grown in the United States in 1949 (Clark & Bayles 1951). Ponca wheat, CI12128, which derived some resistance from Kawvale and a higher level of fly resistance from Marquillo, was released to farmers jointly by the Kansas and Oklahoma experiment stations in the fall of 1951.

REVIEW OF LITERATURE.—The general aspects of insect resistance and the early history of hessian fly resistance have been recorded by Painter (1951). The more detailed information regarding the resistance derived from Marquillo has also been given (Painter *et al.* 1940; Reitz *et al.* 1943). The hessian fly resistance in Marquillo appears to be derived from Iumillo durum and tends to be recessive, but the number of factors responsible is unknown. The hessian fly-resistant variety, Pawnee, has been discussed by Painter and Jones (1945; 1948). Since one of the parents of Ponca is related to Pawnee, the information given in these papers has a bearing on the data discussed here.

Crosses were made between Marquillo spring wheat and several winter wheat varieties in 1932. Because the hybrids lacked winter hardiness, hessian fly-resistant, winter-type segregates from these hybrids were crossed back to other winter wheats. Ponca was derived from the cross of an F_3 plant of the Kawvale ×Marquillo cross to a sister selection of Pawnee from the Kawvale×Tenmarq cross. The resistance present in both parents of Ponca probably involves a low oviposition rate and appreciable tolerance, but antibiosis is the most important feature of the resistance mechanism

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[5] The wheat breeding project in Kansas is a cooperative effort involving the Departments of Agronomy, Botany, Entomology and Milling Industry, as well as branch stations throughout the state. A number of individuals contributed toward the development of Ponca wheat. John H. Parker, L. P. Reitz, C. O. Johnston, and E. D. Hansing all assisted with various phases of breeding and selection of Ponca. Thanks are due also to H. C. Fryer, station statistician, for statistical analysis of some of the data presented.

Table 1.—Hessian fly infestations of early generations of the [(Kawvale×Marquillo) (Kawvale×Tenmarq)] cross, from which Ponca was selected, in comparison with parents and check varieties. 1934–1938.

	Marquillo	Kv-Mq× Kv-Tq[4]	Kawvale× Marquillo 35FN762-2 ♀ Parent	Kawvale× Tenmarq 33FN447 ♂ Parent	Tenmarq
Fall 1934, Marquillo hybrids in F_3					
Manhattan, Kansas	9	—	4[1]	12	97
Parsons, Kansas	2	—	31[1]	—	72
Springfield, Missouri	6	—	23[1]	—	77
Fall 1936, Kv-Mq×Kv-Tq[4] in F_2					
Manhattan, Kansas	0.6	4	0[2]	0[2]	37
Springfield, Missouri	0.8	23	12[2]	78[2]	83
Fall 1938, Kv-Mq×Kv-Tq[4] in F_4					
Manhattan, Kansas	0	0[3]	4[2]	3[2]	31
Springfield, Missouri	1.3	6[3]	5[2]	86[2]	92

[1] Data for row 762 from which the actual parental plant was selected at Manhattan.
[2] Data based on progeny of actual plant used in making the cross.
[3] Data from spaced row from which Ponca was selected in F_4.
[4] [(Kawvale×Marquillo)×(Kawvale×Tenmarq)].

(Painter *et al.* 1940). The hessian fly larvae reach a normal feeding position but do not grow normally (Painter 1951).

MATERIALS AND METHODS; EARLY HISTORY OF THE CROSS AND SELECTIONS FROM IT.—In general, the methods used in this study were those recorded by Painter *et al.* (1940). The hessian fly infestation at Manhattan, Kansas, was induced by the introduction of heavily infested stubble to the area about the nursery. The infestations at Bennington, Kansas, and Springfield, Missouri, were natural ones. Details regarding the infestation of the parents and early generations of the cross which later gave rise to Ponca are presented in table 1. The Kawvale×Tenmarq selection No. 33FN447, a sister selection to Pawnee, was the selection from this cross that had had the highest level of resistance to hessian fly in tests before 1935. It was used, therefore, as the pollen parent in a cross with an F_3 plant of Kawvale ×Marquillo. The latter parental plan was selected from row 762, in the 1935 fly nursery (Painter *et al.* 1940, fig. 7) which was the progeny of a single F_2 plant from the cross Kawvale×Marquillo. A comparison of the infestation of this progeny at the three localities (Table 1) suggests that the plants may have been segregating for some of the genes for resistence derived from Marquillo but were homozygous for genes for fly resistance derived from Kawvale. Some of the other rows in the Kawvale×Marquillo cross were fully susceptible at Manhattan. The row of Kawvale×Marquillo had a low level of leaf rust infection at Manhattan and a relatively high level of tolerance to infestation by jointworm, *Harmolita tritici* (Fitch) at Springfield. The making of the cross in the hessian fly nursery permitted a choice of parental plants that apparently were not infested by the fly.

The F_1 hybrid was grown in the greenhouse in the absence of hessian fly. About 150 plants of the F_2 generation were grown in the Manhattan fly nursery and a similar number at Springfield, Missouri. The low infestation the F_2 population at Manhattan probably reflects the presence of Kawvale resistance, perhaps coming into the cross from both parents. The infestation of the F_2 population at Springfield is similar to that secured in other F_2 populations involving Marquillo resistance (Painter *et al.* 1940, Fig. 4). Seed from selected fly-free plants was sown in the fly nurseries in F_3, but only a slight infestation was secured at Manhattan and a considerable number of the plants were destroyed by wireworms in the Springfield nursery, so that records of hessian fly infestation in that nursery were unreliable. However, selections for growing the F_4 generation were made from rows having the lowest fly infestation.

Populations of F_4 plants from the cross were grown in the two nurseries in 1938–39 and satisfactory infestions were obtained, particularly at Springfield. Data for the spaced row from which Ponca was finally selected are given in table 1. Most of the selections related to this one also were resistant to fly infestation and generally had a low leaf rust infection. Some of these selections and their progenies were grown in F_5 and F_6 plots in the agronomy nursery and were tested in the disease nursery for reactions to rust and to other plant diseases.

HESSIAN FLY INFESTATION RECORDS OF PONCA.—A study of the hessian fly infestation in Ponca wheat in comparison with other selections derived from this and other similar crosses was begun in the fall of 1941. The records accumulated since that time are given in table 2. In this table, the infestation of Ponca is compared with Tenmarq, a susceptible wheat; with Marquillo×Tenmarq 37FN1507, a winter wheat carrying only Marquillo resistance; and with Pawnee a wheat carrying resistance derived from Kawvale. In all of the 52 tests reported, the susceptible variety had an infestation of 20 per cent or more, and in 38 of the tests the infestation amounted to 75 per cent or more. Such infestations are satisfactory for a study of fly reaction. In some of the heavier infestations of Tenmarq, infested tillers of some plants had so many larvae that the tillers were destroyed before the larve matured and the plants were recorded as not infested. Under such conditions the percentage of plants infested in susceptible varieties was relatively low as compared with resistant varieties. Since fewer larvae were feeding on resistant than on the susceptible varieties no tillers were killed before the larvae matured on resistant varieties.

At Manhattan and Bennington in the hard wheat area of Kansas, the hessian

Table 2.—Percentage of plants infested by hessian fly in Ponca and other wheat varieties in tests in Kansas and Missouri, 1941–1949.

Year	No. Comparisons	Marquillo× Tenmarq 37F1507	Ponca CI12128	Tenmarq CI6936	Pawnee CI11669
		Tests in Kansas, (Manhattan, and Bennington)			
1941	2	8%	2%	66%	34%
1942	4	9%	3%	92%	64%
1943	4	3%	1%	72%	43%
1944	3	6%	1%	61%	36%
1945	3	5%	1%	81%	50%
1946	8	9%	3%	75%	49%
1947	3	7%	3%	75%	53%
Total or av.	27	7%	2%	75%	48%
Confidence interval	99%	$1.5 \leq M \leq 8.3$		$18.9 \leq M \leq 35.1$	
		Tests in Missouri, (Springfield)			
1941	1	12%	32%	92%	94%
1942	2	6%	2%	99%	100%
1943	3	2%	1%	70%	56%
1944	3	1%	1%	41%	26%
1945	4	7%	4%	86%	75%
1946	4	8%	4%	99%	94%
1947	4	20%	17%	97%	96%
1948	3	4%	5%	93%	91%
1949	1	10%	0%	89%	95%
Total or av.	25	8%	6%	85%	79%
Confidence interval	95%	$-1.4 \leq M \leq 4.2$		$2.3 \leq M \leq 9.7$	

fly infestations of Tenmarq and Pawnee were similar to those recorded in earlier publications, and indicate the value of the partial resistance present in the latter variety. These differences between Tenmarq and Pawnee and between Ponca and Marquillo×Tenmarq were highly significant statistically. The fact that Ponca had an average of 2 per cent plants infested in this area in comparison with 7 per cent for Marquillo×Tenmarq suggests that Ponca probably has the resistance derived from Kawvale as well as that from Marquillo.

In contrast to the results in the hard wheat area, the data presented in table 2 for the soft wheat area, record even less differences in infestation between Tenmarq and Pawnee and also between Marquillo×Tenmarq and Ponca. The difference between Tenmarq and Pawnee is significant statistically; that between Ponca and Marquillo×Tenmarq is not significant.

At Manhattan, Kansas, and in other localities of central and western Kansas, there has been little contrast in appearance between rows of Ponca and Pawnee when grown side by side under heavy hessian fly infestations (Painter 1951, fig. 30). However at Springfield, Missouri, and other localities in the soft wheat area, the difference in the appearance of these two wheats under heavy fly infestation has been much greater (Fig. 1), and reflects the difference in infestation recorded

Table 3.—Hessian fly infestation of Ponca and other wheat varieties in various localities in the United States. Uniform U.S.D.A. Hessian fly nursery. 1943–1948.[1]

Locality of Tests	No. Tests	Tenmarq CI6936	Pawnee CI11669	Marquillo× Tenmarq 37FN1507	Ponca CI12128
Birds Landing, Calif.	3	61	3.8	1.3	0.3
Lafayette, Ind.	6	51	45	0	0
East Lansing, Mich.	2	37	22	4.5	0
Kearneysville, W. Va.	6	48	40	2.7	1.8
Beltsville, Md.	7	50	47	3.3	3.1

[1] Records, courtesy of W. B. Cartwright and associates, Bureau of Entomology and Plant Quarantine and the State Experiment Stations involved.

Table 4.—Comparison of Ponca and Pawnee for yield and test weight in Kansas. 1943–1951

KIND OF TEST	EASTERN KANSAS			WESTERN KANSAS		
	No. COMPARISONS	Ponca	Pawnee	No. COMPARISONS	Ponca	Pawnee
		Bushels per Acre				
Nursery	22	30.1	29.7	12	26.5	27.2
Plots	41	30.2	30.6	24	29.8	29.7
Farm tests	117	30.1	31.4	82	24.4	25.7
Avg. and total all tests	180	30.4	31.2	118	25.7	26.7
Avg. and total all tests East and West	298	28.5	29.4			
		Test Weight, Pounds per Bushel				
Nursery	22	57.8	57.5	12	57.7	57.4
Farm tests	117	59.0	58.7	82	57.6	57.6
Avg. and total all tests	139	58.8	58.5	94	57.6	57.6
Avg. and total all tests East and West	233	58.3	58.2			

in table 2. Relatively few plants of Tenmarq survived infestation in this area, so that the difference in plant growth between Ponca and Tenmarq has been greater than that shown between Ponca and Pawnee.

Ponca has been grown in the United States Department of Agriculture uniform fly nurseries since 1943. Records are available from five localities from California to Maryland. The records from the uniform nurseries in Kansas and Missouri have been included in table 2. Through the courtesy of Mr. W. B. Cartwright of the Bureau of Entomology and Plant Quarantine and others concerned with these tests, a summary of available data is presented in table 3. Through all of these tests, Ponca has had satisfactory resistance to hessian fly wherever it has been tested.

FIG. 1.—Growth of comparable rows of Ponca (left) and Pawnee (right) at Columbia, Mo., June, 1951 under conditions of heavy hessian fly infestation.

Since 1949 the fly infestation of Ponca has been compared with Pawnee only, but throughout these tests its resistance has continued to be as satisfactory as indicated in earlier records.

OTHER CHARACTERISTICS AND AREA OF ADAPTATION OF PONCA. In addition to its high resistance to the hessian fly, Ponca is nearly equal to Pawnee in yield. In 180 comparisons with Pawnee in eastern Kansas during the years 1943–51 Ponca averaged 30.4 bushels per acre and Pawnee 31.2 bushels (Table 4). Ponca is equal to Pawnee in test weight as indicated by data taken during this same period. In 139 tests in Eastern Kansas, Ponca had a test weight of 58.8 pounds per bushel compared to 58.5 for Pawnee. Outside of the recommended area of adaptation, Ponca was not significantly different from Pawnee in yield or test weight It is not recommended for western Kansas because of its lack of winterhardiness there. Ponca appears to be equal to Pawnee in time of maturity, straw strength, height, milling characteristics, resistance to loose smut, and susceptibility to stem rust. Ponca is superior to Pawnee in several characteristics. The grain does not bleach so readily, sprout in the head, nor shatter as much as

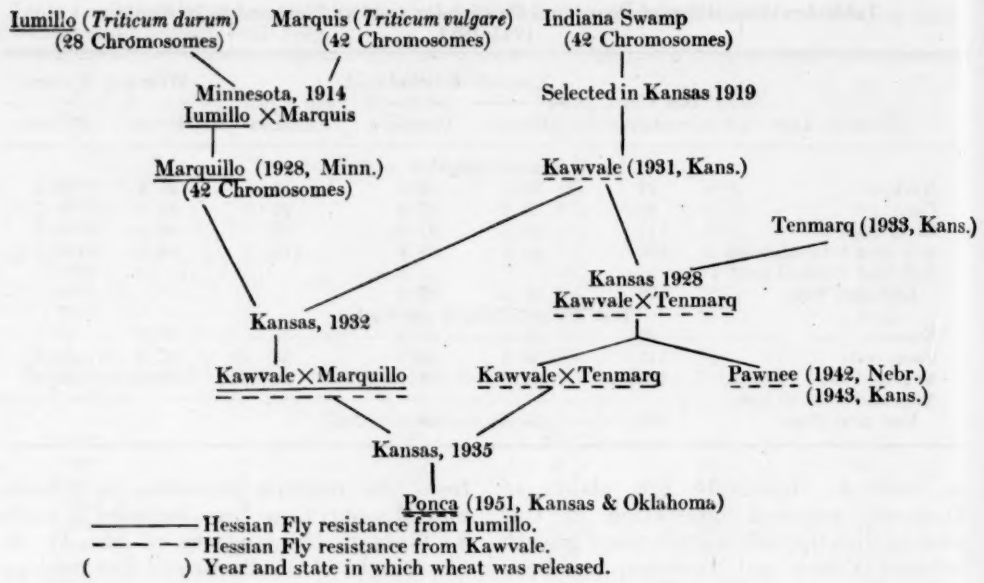

FIG. 2.—Diagrammatic picture of the pedigree of *Ponca* wheat.

Pawnee does if left standing in the field. The quality of the protein for bread baking is superior to that of Pawnee. The variety is resistant to leaf rust, being superior to any variety adapted to Kansas. In eastern Kansas Ponca should outyield Pawnee, when leaf rust and hessian fly are present in damaging amounts. Ponca is susceptible to bunt while Pawnee is resistant to it under ordinary field conditions, but this disease is readily controlled by seed treatment. Its lack of winter hardiness will limit the value of Ponca for western Kansas. Its value will be realized in eastern Kansas however, where winter damage is less common and where Ponca will give the greatest protection against leaf rust and hessian fly.

DISCUSSION—POSSIBLE VALUE OF PONCA FOR CONTROL OF HESSIAN FLY AND POSSIBLE EFFECT ON FLY POPULATION COMPARED TO PAWNEE.—The pedigree of Ponca is diagrammed in figure 2. This figure also indicates the sources of the fly resistance carried by this wheat. Ponca has been approximately equal to Pawnee in yield, especially in the eastern half of Kansas. The fly and leaf rust resistance of Ponca in this area should contribute to some general increase in the yield level when Ponca becomes more generally grown. The effect of the growing of Ponca on the fly population and on hessian fly control may best be judged by what has happened to the fly infestation in central Kansas as a result of the widespread growing of Pawnee. The period since 1940 for the most part has been highly favorable to the development of hessian fly in Kansas; yet since 1947, plants infested by hessian fly have been increasingly difficult to find in central Kansas although some susceptible wheat is still being grown. The widespread growing of Pawnee therefore has had a greater effect on infestation and on the general level of fly population than could have been predicted on the basis of experimental results. In contrast to the central Kansas situation where Pawnee is resistant, there have been some outbreaks of fly infestations reported during this period in eastern Kansas where Pawnee is much less resistant. In central Kansas, according to nursery results, Pawnee carries from one-half to one-third the infestation of susceptible wheats, while throughout the wheat area, nursery tests indicate that Ponca carries about 95 per cent resistance (Table 2). Where Ponca becomes extensively grown, there should be a greater reduction in the fly population and better fly control than that given by Pawnee, if one may judge by what has happened in central Kansas since Pawnee has been extensively grown there. Hence we may expect Ponca to contribute further toward the elimination of hessian fly as a factor in Kansas wheat production.

SUMMARY.—1. Ponca wheat, a selection

from the cross [(Kawvale×Marquillo)×(Kawvale×Tenmarq)], has been produced in part as a means for the control of the hessian fly.

2. Ponca probably carries resistance to hessian fly derived from its Kawvale as well as its Iumillo ancestry. Ponca has been resistant to the hessian fly wherever grown during the period 1941 to 1951.

3. Ponca had 2 per cent of the plants infested in 27 comparisons, in the hard wheat area of Kansas and 6 per cent in 25 comparisons in the soft wheat area of Missouri. The susceptible Tenmarq variety had 75 per cent and 85 per cent infestation in the same comparisons.

4. Ponca has greater resistance to hessian fly and leaf rust but less bunt resistance and winter hardiness than Pawnee, the variety most commonly grown in eastern Kansas. Ponca does not differ significantly from Pawnee in most other characteristics of economic importance.

5. If Ponca is grown extensively on farms in eastern Kansas, the hessian fly population may be so reduced that this insect will be largely eliminated as a factor depressing wheat production.

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Relation between Natural Enemies and DDT-Induced Increases in Frosted Scale and Other Pests of Walnuts

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Dosages of DDT recommended for control of codling moth on English walnuts in southern California have in some instances resulted in increased populations of the walnut aphid, *Chromaphis juglandicola* (Kltb.); the two-spotted spider mite, *Tetranychus bimaculatus Harvey;* the European red mite, *Paratetranychus pilosus* (C. and F.); and the frosted scale, *Lecanium pruinosum* Coq. Abnormal increased in populations of the same pests have been shown to be associated with DDT treatments on English walnuts in northern California, and decreased DDT dosages have been recommended to ovoid these destructive increases (Michelbacher *et al.* 1946; Middlekauff *et al.* 1947). In southern California the severity of such outbreaks has diminished where DDT dosages have been lowered. Nevertheless, for occasional severe infestations of codling moth, DDT must be used at dosages which provoke serious increases of the pests mentioned above.

A number of other insecticidal materials besides DDT have shown tendencies toward increasing populations of aphids and spider mites on walnuts (Michelbacher *et al.* 1947). Specific reasons for these observed increases in pest populations have been difficult to ascertain, although such increases have often been tentatively associated with the destruction of natural enemies by the insecticide used. An indisputable explanation has rested on a better knowledge of the relative effectiveness of the natural enemies and of the possible toxicity, to the parasites, of insecticidal adjuvants often included in the spray mixtures.

DDT has been shown to reduce significantly the activity of predators of

[1] Paper from University of California Citrus Experiment Station, Riverside, California.

aphids and of spider mites, including the lacewing and coccinellid and coniopterygid mite predators, on citrus in southern California (DeBach & Bartlett 1951). A similar reduction in predator populations is responsible, at least in part, for increased populations of both aphids and red spiders on walnuts in southern California, following applications of DDT. Although the residual action of DDT does not arrest the host increase materially, it does act on the general predators in such a way as to release the oncoming host generations from the influence of their natural enemies, and so causes the rapid increase or flareback of the pests. Because the deterrent action of DDT on general predators of walnut pests failed to account for the increased abundance of frosted scale, special emphasis was placed on the examination of this pest and its natural enemy associations.

FROSTED SCALE INCREASES.—Frosted scale has but rarely been a pest of serious proportions on walnuts in the past in southern California, although occasionally observed as of minor incidence. In the last few years, however, there has been considerable evidence that increase in frosted scale is, to a certain extent, a general cyclic event not necessarily connected with direct application of DDT, since even in districts where lead-arsenate programs have been adhered to, the scale has shown some increase over previous numbers.

This cyclic increase in frosted scale has paralleled an abnormal increase in a number of lecaniine scales attacking citrus. It has been suggested that such trends may be associated with a cycle of cold, dry winters having an unfavorable effect on the development of the parasitic Hymenoptera which formerly exerted greater influence in control. This explanation is similar to that offered by Flanders (1949) for the inability of *Metaphycus helvolus* (Compere) to hold its black scale host on citrus under the favorable balance formerly maintained. There is no evidence that the apparent cyclic increase of frosted scale in non-DDT-treated orchards is the result of an over-all decrease in natural enemy activity due to a lethal effect of DDT-treated acreage on migrant parasites, or "trap effect," as it is called. Such an explanation may apple in some limited areas, but the non-use of DDT in entire districts where limited increases in frosted scale have been observed precludes so general an explanation.

A critical study of natural enemy associations connected with DDT-induced increases in frosted scale in southern California has shown the increase to be due to the direct effect of DDT residues upon a single parasite species, *Metaphycus californicus* (Howard) [Encyrtidae], the dominant parasite of frosted scale on walnuts in this area

The decrease in activity of *Metaphycus californicus* following DDT treatment corresponds closely with that determined for the black scale parasite *Metaphycus helvolus*. With the latter parasite, field dosages of DDT on citrus, comparable to the lower dosages used on walnuts, have been shown to be toxic for period ranging up to 3 or more months. Higher dosages remain toxic for considerable longer periods.

PARASITE-HOST RELATIONS.—A detailed analysis of the action of *Metaphycus californicus* in southern California is necessary for complete understanding of the manner of upset of biological control associated with DDT treatment. This species, so far as can be determined, attacks only frosted scale. It has not been taken on any of the related lecaniine scales that occur in southern California. It comprises nearly 100 per cent of the parasitic fauna of its host. Individual specimens of *Blastothrix sericea* Dalm. parasitic on frosted scale on walnuts have been encountered only rarely in southern California. The scarcity of hyperparasitic species has been most noticeable. *Thysanus* sp. has been taken as a secondary parasite on *Metaphycus californicus* only in very limited numbers.

Metaphycus californicus attacks frosted scale at every stage of development, from approximately 0.6 mm. in length to maturity, thereby demonstrating an exceptional adaptability to its host. In the smaller stages of host development the parasite is solitary, but gregariousness increases progressively with the size of the scale, and it is not unusual to find 25 or more adults emerging from a single full-grown host. Emergence is through holes cut by the adults in the dorsum, and occasionally even in the venter, of the scale derm. The major hatch of frosted scale on English walnuts in southern California occurs in May and June, and it is not uncommon to find

adults of *M. californicus* in abundance in the field at this time. At this time, also, some few parasites are still inhabiting the egg-producing adult female scales.

The scales develop very slowly during the late summer, and those from the May hatch begin to show evidence of parasitization by *Metaphycus californicus* in September and October, at which time many scales found on the leaves show the characteristic mummification of the body. During the early winter months parasite activity increases steadily, and the dropping of leaves bearing many parasitized and unparasitized scales tends to benefit the parasite population by decreasing the number of scales and at the same time permitting survival of parasities on the dropped leaves. Migration of part of the unparasitized scales to the past season's new wood is therefore accompanied by an increase in percentage of parasitism until, by late February and March, when the male scales emerge, parasitization has often built up to an extremely high level. By February or March, some scales have increased in size to the extent that two or three parasites may inhabit one scale. Scale development in March, April, and May is very rapid. During this growth period, parasitization continues uninterruptedly, with all host stages susceptible to attack until, in May and June, *M. californicus* is found emerging from frosted scales that have appreciable numbers of eggs hatching beneath the scale body. This uninterrupted attack upon all host stages is one of the unusual characteristics which makes natural control by this parasite species so efficient.

DDT-PARASITE RELATIONS.—From an analysis of the given seasonal host-parasite relationship, it is easy to picture the effect on the parasite of DDT applications for codling moth. May applictions at dosages used (approximately 6 pounds actual DDT per acre) retard parasite activity only during the late adult and early larval stages of the scale, and thus are applied at the least detrimental period, so far as the parasites are concerned. This minor break in the continuity of parasite activity is sufficient at times to partially upset the natural control, but if residue retention is not too great (that is, if dosages are kept as low as is feasible), the increase in frosted scale is generally only temporary and is easily brought under control by the parasite. If second treatments are required for severe codling moth infestations, parasite-killing residues extend dangerously into the late summer months and permit serious infestations of the scale which may not be amenable to complete control by the parasite. It is suggested that where relatively heavy infestations of frosted scale exist, a schedule of reduced DDT dosages, and particularly the use of only a single application, will be followed by satisfactory reduction of the infestations through the action of *Metaphycus californicus*.

SUMMARY.—In southern California, increases in populations of the walnut aphid, *Chromaphis juglandicola* (Kltb.), and of the two-spotted spider mites, *Tetranychus bimaculatus* Harvey, and the European red mite, *Paratetranychus pilosus* (C. and F.), are associated with decreases in populations of coccinellid, lacewing, and coniopterygid predators caused by DDT spray residues.

DDT-associated increases in the frosted scale, *Lecanium pruinosum* Coq., are entirely due to the deleterious action of DDT residues on the encyrtid parasite *Metaphycus californicus* (Howard), its predominantly effective natural enemy. This parasite attacks all stages of its host from that approximately 0.6 mm. in length to maturity.

Ordinarily, DDT sprays for codling moth are applied during the period when they are least detrimental to parasite activity, but heavy dosages and double treatments dangerously extend the periods of harmful residue retention.

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Toxicity of Insecticides to Some Predaceous Insects on Cotton[1]

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Since the development of the recent organic insecticides there has been increasing interest in their effect upon the beneficial insects. Loftin (1945) noticed an increase in *Aphis gossypii* Glov. and *Tetranychus* sp. following the use of DDT. Newsom & Smith (1949) suggested that the chlorinated hydrocarbon insecticides were affecting the natural balance that exists between the cotton aphid, spider mite, and the bollworm and their natural enemies. Ripper *et al.* (1951) believed the problem could be solved by the use of selective insecticides, but DeBach (1951) blamed DDT for the increase in scale insects, mites, and mealybugs on citrus, and thought the problem should be approached from an ecological view. Ullyett (1948) suggested a combination of insecticide treatment and biological control as the most satisfactory method of combating insect pests.

In the summer of 1951 laboratory and field tests were conducted at the Delta Branch Experiment Station, Stoneville, Miss., to determine which insecticides had the least effect upon the beneficial insects found on cotton.

PREDATORS FOUND ON COTTON.—During the investigation the following predators were found to be present:

Coleoptera
- Coccinellidae
  - *Adalia bipunctata* (L.)
  - *Coleomegilla maculata* (Deg.), spotted lady beetle
  - *Coccinella 9-notata* Herbst
  - *Cycloneda munda* (Say)
  - *Hippodamia convergens* Guerin, convergent lady beetle
  - *Olla abdominalis plagiata* (Casey)
  - *Olla abdominalis* (Say)
  - *Scymus* sp.

Hemiptera
- Anthocoridae. *Orius insidiosus* (Say)
- Lygaeidae. *Geocoris punctipes* (Say), big-eyed bug.
- Nabidae. *Nabis ferus* (L.), gray damsel bug
- Reduviidae

Neuroptera. Chrysopidae. *Chrysopa* sp.

Orthoptera. Mantidae

Frequent observations were made in the field to determine the food sought by the various species. The coccinellids were consistently observed feeding upon aphids and spider mites. On one occasion a coccinellid larva was seen eating into the dorsal portion of a *Heliothis* larva, and *Coleomegilla* was observed attacking eggs of the yellow-striped armyworm, *Prodenia ornithogalli* Guen. *Geocoris punctipes* was often observed with a mirid nymph impaled on its beak, whereas *Nabis ferus* seemed to prefer leafhoppers. On two occasions adult and nymphal *Geocoris* failed to pierce eggs of the *Heliothis* moths while in confinement in the insectary. The eggs were probably those of *H. armigera* (Hbn.) but *H. virescens* (F.) was also present in the cotton fields.

A review of the literature on the food and feeding records of predaceous insects showed that *Orius insidiosus* was considered the most important enemy of the spider mite *Septanychus* sp. (Iglinsky and Rainwater 1950). Barber (1936) gave *Orius* credit for destroying 38 per cent of the eggs of the bollworm from 1924 to 1927, and Fletcher & Thomas (1943) with destroying 52 per cent of the larvae. Ewing and Ivy (1943) list this species as an important enemy of the cotton aphid. *Aphis gossypii* Glov. McGregor and McDonough (1917, pp. 39 and 43) found that *Geocoris punctipes* consumed an average of 83, and *Orius insidiosus* 33, spider mites per day.

This is not a complete list of the food of these predators, but rather an attempt to illustrate their importance in the cotton field and the necessity for maintaining these individuals at high population levels.

LABORATORY TESTS.—Laboratory tests were conducted on several of the more abundant predators. The experiments were started in June and continuted through August. Cotton cuttings to be sprayed or dusted were carefully selected so that each contained two leaves and approximately the same leaf area. The cuttings were kept fresh during the four-day test period by placing them in vials

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Table 1.—Results of laboratory tests to determine the effect of various insecticides on predators of cotton insects.

Insecticide	Pounds per Acre	Average Per Cent Mortality			
		After 48 Hours		After 96 Hours	
		Sprays	Dusts	Sprays	Dusts
Nabis ferus					
Compound 269	0.1	75	83	100	100
Compound 711	.2	57	—	67	—
Compound 923	2	88	—	100	—
DDT	.5	100	0	100	25
Geocoris punctipes					
Compound 923	2	24	—	50	—
DDT	.5	75	51	100	100
Coleomegilla maculata					
Aldrin	0.25	28	13	33	20
Chlordane	1	23	16	64	33
Compound 269	.1	63	45	70	77
Compound 711	.2	22	—	30	—
Compound 923	2	28	—	54	—
DDT	.5	52	18	76	39
Dieldrin	.15	19	12	54	40
EPN	.2	100	100	100	100
BHC, gamma	.4	69	82	87	89
Heptachlor	.35	17	14	34	36
Parathion	.1	100	100	100	100
Toxaphene	2.5	57	64	78	85
Calcium arsenate	10.	—	51	—	73
Hippodamia convergens					
Aldrin	0.25	11	0	31	2
Chlordane	1	—	0	—	7
Compound 269	.1	3	14	5	38
Compound 711	.2	17	—	7	—
Compound 923	2	7	—	9	—
DDT	.5	0	12	8	0
Dieldrin	.15	14	0	23	8
EPN	.2	90	73	100	90
BHC gamma	.4	33	11	48	26
Heptachlor	.35	10	0	25	6
Parathion	.1	100	100	100	100
Toxaphene	2.5	34	40	52	61
Scymnus sp.					
Aldrin	0.25	31	—	44	—
Chlordane	1	55	—	17	—
Compound 269	.1	41	—	70	—
Compound 711	.2	16	—	5	—
Compound 923	2	78	—	100	—
DDT	.5	45	—	84	—
Dieldrin	.15	27	—	51	—
BHC gamma	.4	96	—	92	—
Heptachlor	.35	43	—	54	—
Toxaphene	2.5	72	—	84	—

containing a stock nutrient solution. The vials were buried in dirt and sand-filled flower pots. Gauze-covered lantern globes served as cages.

Equipment for treating the plants consisted of a dusting tower and a rotary or turntable sprayer. A pressure necessary to disperse the dust was supplied by a plunger of the doorstop variety. The sprayer was calibrated to put out the desired toxicant in one revolution.

All test insects were collected in the field with a sweep net, and exposed to the treated plants. Since they too were not subjected to direct treatment, the effect of the insecticides depended on their activity on the treated surface.

Mortalities were calculated according to Abbott's formula. Ten individuals were used per replicate in the case of *Coleomegilla maculata* and *Hypoderma convergens*, and five individuals of the other species. Tests with *Hypoderma convergens*, *Scymnus* sp., and *Geocoris punctipes* were replicated six times, those with *Coleomegilla maculata* nine times; the dust treatments on *Nabis ferus* were replicated three times and the sprays six times.

The results are summarized in table 1. Most insecticides tested against *Nabis ferus* were detrimental to this bug. At the end of 96 hours the only insecticides that did not completely eliminate this predator were compound 711 when applied as a spray and DDT when applied as a dust. *Geocoris punctipes* was virtually eliminated by all insecticides except compound 923. Aldrin, chlordane, dieldrin, EPN, BHC, heptachlor, parathion, and toxaphene (not included in table) all caused 100 per cent mortality of both species within 48 to 72 hours.

Compound 269, BHC, toxaphene, and calcium arsenate caused mortalities in excess of 70 per cent, but only EPN and parathion completely eliminated *Coleomegilla maculata*. Aldrin, compound 711, and heptachlor were the least effective.

Hippodamia convergens is relatively tolerant to many of the insecticides. It would be difficult to single out any one insecticide as having the least effect on this predator, since aldrin, chlordane, compounds 269, 711, and 923, DDT, dieldrin, and heptachlor caused all less than 10 per cent mortality when applied as either a spray or a dust.

Chlordane and compound 711 had the least effect on *Scymnus* sp. It is probable that the percentage for chlordane is too low, since there was an unusually steep drop between the 48- and 96-hour counts.

All the insecticides affected the predators to some extent. However, no conclusions can be drawn as to the relative effect of dusts and sprays. DDT was the only insecticide that consistently caused lower mortalities when used as a dust. Compound 711 caused the lowest mortality of all the insecticides used.

Since the coccinellids comprised approximately 70 per cent of the predator population at Stoneville, the data on these insects may be used as a means of dividing the insecticides into two groups—those having a moderate effect and those causing a high mortality. The first group consists of aldrin, chlordane, compounds 711 and 923, dieldrin, and heptachlor.

FIELD TESTS.—These field plots, which

Table 2.—Results of field tests to determine the effect of insecticides on various predators of cotton insects. Number of individuals collected in 100 net strokes after each application.

INSECTICIDE (pounds per acre)	*Hippodamia convergens*	*Coleomegilla maculata*	*Coccinella 9-notata*	*Scymnus* sp.	*Coccinellidae*	*Chrysopa* sp.	*Nabis ferus*	*Geocoris punctipes*	*Orius insidiosus*	TOTAL	PER CENT REDUCTION UNDER CHECK
Sprays applied June 25 and July 9											
Check (untreated)											
Before treatment	30	61	1	3	3	4	11	5	17	135	
After 48 hours	20	14	0	0	3	0	7	3	4	51	
Dieldrin 0.15											
Before treatment	59	51	0	3	9	6	10	2	13	153	
After 48 hours	29	15	0	0	8	0	5	0	2	59	−1
DDT 0.5											
Before treatment	81	41	3	0	1	4	23	2	9	164	
After 48 hours	15	3	0	3	3	0	1	0	1	26	22
Toxaphene 2.5											
Before treatment	33	14	1	1	5	5	5	2	10	76	
After 48 hours	13	4	0	1	2	0	1	1	3	25	5
Sprays applied August 2 and 7											
Check (untreated)											
Before treatment	10	34	—	21	46	—	35	3	20	169	
After 48 hours	12	43	—	32	38	—	22	3	8	158	
Dieldrin 0.3											
Before treatment	3	35	—	12	31	—	12	2	0	95	
After 48 hours	6	32	—	17	8	—	0	0	0	63	28
DDT 1											
Before treatment	1	10	—	10	6	—	12	0	1	40	
After 48 hours	0	1	—	3	3	—	0	0	2	9	71
Toxaphene 3											
Before treatment	0	24	—	6	8	—	11	0	0	49	
After 48 hours	1	10	—	3	5	—	0	0	0	19	55

were primarily set up for studies of cotton pests, were utilized for studying the effects of field-applied insecticides on predaceous populations. One plot was treated with dieldrin, one with DDT, and one with toxaphene. One plot was left untreated as a check. Each plot was 40 rows wide and approximately 200 yards long. All insecticides were applied as sprays with a tractor equipped with a four-row spray rig. Nine applications were made, as follows: May 25 and 28, June 5 and 25, July 9, 17 and 23, and August 2 and 7. On August 2 and 7 the dosage of dieldrin was increased from 0.15 pound per acre to 0.3 pound, DDT was increased from 0.5 pound to 1 pound, and toxaphene from 2.5 pounds to 3 pounds. Population counts were obtained by making 100 strokes in each plot with a 16-inch sweep net. Counts were taken before, and 24 and 48 hours after, each treatment.

As shown in table 2, dieldrin at both rates of application caused less reduction in total predators than did either DDT or toxaphene. As in the laboratory tests, the hemipterous insects were more seriously affected than the coccinellids. Although DDT caused higher reduction than toxaphene, the number of predators were never so great in the toxaphene plot.

Table 3 shows that the coccinellids were the most abundant predators and *Coleomegilla maculata* was the most abundant species. The figures for *Chrysopa* sp. are probably too low, since these predators take flight with the least disturbance. There was an ebb in the predator population in mid-July; not only in this field but in other fields removed from this test. The peak of the predator population appeared to occur early in June with a second peak early in August.

During the period when the predators were scarce on cotton, it was found that they were very numerous and breeding heavily on corn. The coccinellids *Orius* and *Chrysopa* were especially abundant, but all species found on cotton were also present on corn. This build-up on corn may explain why the number of predators decreased as the distance from nearby corn field increased. This observation suggests the possibility of increasing the predators

Table 3.—Populations of predaceous insects found on untreated cotton at different times during the season. Numbers collected per 100 net strokes.

PREDATOR	JUNE 25 AND 26	JULY 9 AND 10	JULY 19	JULY 24 AND 25	AUGUST 2 AND 3	AUGUST 7 AND 8	AUGUST 17	AVERAGE
Hippodamia convergens	39	11	7	4	11	4	4	6.7
Coleomegilla maculata	87	6	2	4	32	49	21	16.8
Coccinella 9-notata	3	0	0	0	0	0	0	0.3
Scymnus sp.	3	1	1	4	18	33	9	5.8
Cycloneda munda	0	0	0	0	0	1	2	0.3
Coccinellide	14	15	11	54	39	28	15	14.7
Chrysopa sp.	3	2	1	0	0	0	2	0.7
Nabis ferus	22	1	0	5	21	43	3	7.9
Geocoris punctipes	5	7	1	0	4	4	0	1.8
Orius insidiosus	11	15	8	4	16	16	1	5.9
Reduviidae	0	0	0	0	1	1	0	0.1
Total	187	58	31	75	142	179	57	60.7

on cotton by planting a crop harboring similar insects adjacent to cotton.

The application of insecticides during this midsummer ebb in predators, which would be prolonged by the natural lag in predators in relation to their host, coupled with the use of some of the less potent insecticides, may suggest a means of alleviating the wide-scale destruction of predators and allow them to add their controlling effect.

SUMMARY.—During the summer of 1951 laboratory and field tests were conducted to determine which insecticides had the least effect on the beneficial insects found on cotton. The insecticides tested were aldrin, chlordane, compounds 269, 711, and 923, DDT, dieldrin, EPN, BHC, heptachlor, parathion, toxaphene, and calcium arsenate.

Among the predators found on cotton were eight coccinellids, an anthocorid, a lygaeid, a nabid, a chrysopid, and several reduviids and mantids.

All the insecticides used reduced the predators. However, compound 711 at the rate of 0.2 pound per acre caused the lowest mortality. EPN and parathion consistently eliminated the predators within the 4-day test period. In the field tests dieldrin applied at 0.15 and 0.3 pound per acre caused less reduction in predators than either DDT or toxaphene. In both the laboratory and field tests the hemipterous insects were more seriously affected than the coccinellids. *Hippodamia convergens* was the species most tolerant to insecticides, but it was not abundant after June.

The peak in predator populations occurred in June and the lowest ebb in mid-July. During this ebb the predators were very abundant on corn. This apparent build-up on corn may explain why the predators were more numerous on cotton adjacent to corn and suggest the possibility of increasing the predators on cotton.

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Insecticidal Control of Thrips on Cotton[1]

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Entomologists have recognized that the injury caused by thrips may be a limiting factor in producing a normal yield of cotton. In those years when the weather conditions were favorable for thrips development, losses in stands of cotton resulted from this pest. In most years, thrips are sufficiently abundant to retard fruiting and cause malformed plants.

Investigations have been continued at this Station in an effort to evaluate new insecticides for the control of thrips. Results of tests reported by Gaines (1934), Fletcher & Gaines (1939), Fletcher *et al.* (1947), and Gaines *et al.* (1947, 1948, 1951) indicated that insecticides reduced the thrips population and in some cases reduced the thrips injury, but failed to produce an increase in total yield. In most cases, fruit was set earlier on the cotton in plats where thrips were controlled. It was also pointed out that factors other than thrips may be responsible for some of the so called "thrips injured" plants. Planters have realized as indicated by their continued use of insecticides for thrips control that it is important to prevent damage from this pest. If the first fruit is destroyed, the plants seem to grow vegetatively requiring a considerable period of time before normal fruiting is resumed. This delay in fruiting results in a later crop often requiring additional applications of insecticides to control the late season pests.

In the tests herein reported the following species of thrips were found attacking cotton: *Frankliniella tritici* (Fitch), *F. fusca* Hinds and *F. exigua* Hood. The thrips population records were made in the usual manner. Twenty plants were collected at random in each plat for examination. These plants were placed in suitable containers immediately after being pulled for transporting to the laboratory. They were examined for thrips by striking the tops against a coarse hardware cloth above a black background. The above named species were found on the cotton in all plats during the entire test period and no attempt was made to record the population of the individual species. However, there was no indication that any of the insecticides were specific in their action.

The sprays were applied with a power sprayer developed for spraying small plants. The machine was equipped with motors to operate the gear pump and to propel the machine at 4.5 miles per hour. The emulsion sprays were applied at 60 pounds pressure at the rate of approximately 2.5 gallons per acre using a cone nozzle over each row. An auxiliary nozzle which delivered spray into a jar made it possible to measure the exact dosage applied to each plat.

The percentages of control were calculated by Abbott's formula. The thrips population data were analyzed by analysis of variance. The minimum differences required for significance between treatment averages are shown in the tables.

Experiment 1, shown in table 1, was conducted for the purpose of evaluating the following materials for thrips control: (1) parathion, (2) EPN,[2] (3) DDT, (4) gamma BHC, (5) aldrin, (6) dieldrin and (7) toxaphene. The plats were arranged in randomized blocks. Each treatment and the check were replicated four times. Each plat was 15 rows wide and of sufficient length to make one-eighth acre. Spray applications were made on May 3 and May 18, at the average rates shown in table 1. Infestation records were made on the 1st, 3rd, 5th, 9th and 11th day following the first application and on the 1st, 3rd, 5th and 7th day following the second application. Averages of thrips population taken on the above dates are shown in table 1 as the seasonal average. All the detail records are not shown. However, all materials gave almost complete control on the first day following the first application. The data in the table indicate the residual toxicity of the materials.

Dieldrin, toxaphene and DDT were effective for 5 days but all materials were ineffective by the eleventh day following the first application. All the materials were effective for a 7-day period following the

[1] Technical contribution no. 1588 Texas Agricultural Experiment Station in cooperation with the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture. Thanks are due W. J. Mistric for assistance in conducting these tests.

[2] Ethyl p-nitrophenyl thionobenzenephosphonate.

Table 1.—Average number of thrips on 20 plants and per cent control following treatments as indicated in experiment 1.

Insecticide and Rate[1]		Initial Population	Days After 1st Application: 5 — No. and Per Cent Control		Days After 1st Application: 11 — No. and Per Cent Control		Days After 2nd Application: 3 — No. and Per Cent Control		Days After 2nd Application: 7 — No. and Per Cent Control		Seasonal Average — No. and Per Cent Control	
EPN	.08	31.0	24.0	55.6	61.5	0.0	2.0	98.6	18.5	86.7	20.9	73.9
Parathion	.08	35.8	27.5	55.9	89.8	0.0	60.0	62.9	44.0	72.5	44.5	51.9
DDT	.26	31.8	13.5	75.6	68.8	0.0	19.5	86.4	33.5	76.4	25.7	68.8
Gamma BHC	.08	33.2	24.5	57.9	66.5	0.0	66.0	56.3	26.0	82.6	45.1	47.8
Aldrin	.08	26.5	17.0	63.2	39.2	5.6	25.0	79.2	24.0	79.8	23.4	65.7
Dieldrin	.08	40.5	2.2	96.8	42.5	33.1	7.0	96.2	5.5	97.0	12.4	88.2
Toxaphene	1.05	30.2	7.5	85.8	70.5	0.0	.5	99.6	9.0	93.4	19.4	75.4
Check		36.0	62.8		56.5		163.0		161.0		93.2	
Minimum difference for significance at .05 level											15.7	

[1] Pounds active ingredient per acre.

second application. Using the seasonal averages as the criteria, dieldrin, toxaphene, EPN, DDT and aldrin were more effective than either parathion or gamma BHC.

Experiment 2, shown in table 2 was also for the purpose of evaluating the following materials for thrips control: (1) parathion, (2) EPN, (3) DDT, (4) gamma BHC-DDT (3–5), (5) aldrin, (6) dieldrin and (7) toxaphene. Since gamma BHC did not exhibit sufficient residual toxicity in experiment 1 it was deemed advisable to add DDT. The plats were arranged in randomized blocks. Each treatment and the check were replicated four times. Each plat was 12 rows wide and of sufficient length to make one-eleventh of an acre. Spray applications were made on late planted-cotton June 7 and June 22 at the average rates shown in table 2. Infestation records were made on the first, fourth, seventh, eleventh and fourteenth day following the first application and on the first, third, sixth and tenth day following the second application. The average populations on the above dates are shown as seasonal averages in table 2. All materials were highly effective for a period of 2 or 3 days following the first application, but by the fourth day the toxicity of parathion and gamma BHC-DDT was greatly reduced. Dieldrin was the most effective material on the fourteenth day following the first application, and again on the eleventh

Table 2.—Average number of thrips on 20 plants and per cent control following treatments as indicated in experiment 2.

Insecticide and Rate[1]		Initial Population	Days After 1st Application: 4 — No. and Per Cent Control		Days After 1st Application: 14 — No. and Per Cent Control		Days After 2nd Application: 3 — No. and Per Cent Control		Days After 2nd Application: 10 — No. and Per Cent Control		Seasonal Average — No. and Per Cent Control	
EPN	.07	85.5	4.5	81.2	102.0	29.8	3.5	96.2	46.5	17.2	29.5	62.0
Parathion	.13	63.8	12.0	32.6	107.5	0.7	30.5	55.7	38.0	9.2	33.0	43.1
DDT	.25	71.8	6.8	66.3	99.5	18.3	28.0	63.8	35.0	25.7	32.6	50.2
Gamma BHC-DDT (3–5)	.20	65.5	9.8	46.7	117.0	0.0	42.0	40.6	32.5	24.4	42.0	29.5
Aldrin	.07	84.8	6.2	73.6	71.5	50.3	21.5	76.5	35.0	37.1	26.0	66.3
Dieldrin	.07	90.5	3.2	87.1	58.0	62.3	3.5	96.4	15.0	74.8	14.2	82.7
Toxaphene	.98	54.8	1.5	90.2	88.0	5.4	7.5	87.3	19.5	45.8	19.0	61.9
Check		66.2	18.5		112.5		71.5		43.5		60.5	
Minimum difference for significance at .05 level											13.0	

[1] Pounds active ingredient per acre.

Table 3.—Average number of thrips on 20 plants and per cent control following treatments as indicated in experiment 3.

Insecticide and Rate[1]		Initial[2] Population	Days After Application: 2 — Number and Per Cent Control		7 — Number and Per Cent Control		13 — Number and Per Cent Control		Seasonal Average — Number and Per Cent Control	
Toxaphene Dust	.95	45.2	22.8	64.4	12.8	82.8	71.5	14.7	35.7	51.8
Toxaphene Spray	.80	49.2	.2	99.7	23.5	71.0	41.5	54.5	21.7	73.1
Aldrin Dust	.11	43.5	35.0	43.2	32.5	54.6	44.0	45.5	37.2	47.8
Aldrin Spray	.10	22.0	10.2	67.2	19.2	47.0	30.5	25.3	20.0	44.4
Dieldrin Dust	.07	42.2	8.8	85.3	16.8	75.8	50.0	36.1	25.2	63.5
Dieldrin Spray	.06	25.5	1.2	96.7	14.2	66.1	52.0	11.2	19.1	54.2
Check		46.9	66.4		77.1		87.0		76.8	
Minimum difference for significance at .05 level[3]									28.0	

[1] Pounds active ingredient per acre.
[2] Initial record made May 14.
[3] For whole plats including both dust and spray of each insecticide summed.

day following the second application.

Using the seasonal averages as the criteria, dieldrin, toxaphene and aldrin were equally effective. In this test, DDT, gamma BHC-DDT, EPN and parathion did not exhibit as high residual toxicity as the other compounds. The residual toxicity of EPN and DDT was better in experiment 1 than in experiment 2 due, perhaps, to the cooler weather existing during May.

Experiment 3, table 3, was conducted for the purpose of evaluating toxaphene, aldrin and dieldrin in both dust and spray formulations for thrips control. In this test a split-plat design was used. Each whole plat was 30 rows wide and 96.8 feet long and each subplat was 15 rows wide and 96.8 feet long or one-ninth acre in size. One subplat in each whole plat was selected at random to receive the insecticide in the dust form while the remaining subplat received the same insecticide in spray form. Applications of insecticides were applied on May 2 and May 15. Heavy rains following the first application reduced the thrips populations completely on all plats including the checks. No evaluation could be made of the insecticides following this application. By May 15, the population had increased and a second application was made. Records of the thrips population were made on the second, seventh and thirteenth day following the second application as shown in table 3.

The dust and spray formulations of toxaphene, aldrin and dieldrin were equally effective. There was little difference in the residual toxicity of dust and spray formulations and there was no difference in the toxicity of aldrin, dieldrin and toxaphene at the dosages used.

Experiment 4, table 4, was conducted for the purpose of evaluating the following

Table 4.—Average number of thrips on 20 plants and per cent control following treatments as indicated in experiment 4.

Insecticide and Rate[1]		Initial Population	Days After 1st Application: 2 — Number and Per Cent Control		10 — Number and Per Cent Control		Days After 2nd Application: 3 — Number and Per Cent Control		15 — Number and Per Cent Control		Seasonal Average — Number and Per Cent Control	
OMPA	.50	104.2	49.8	27.1	119.0	35.5	10.0	94.8	81.5	61.1	75.0	64.8
Systox	.52	76.2	.5	99.9	23.5	82.6	4.0	99.9	39.0	74.6	24.0	84.6
Toxaphene	.77	104.2	9.8	85.7	31.5	82.9	5.0	99.9	81.0	61.4	36.1	83.1
Parathion	.15	106.2	.8	99.9	52.5	72.1	6.0	99.9	98.0	54.1	39.3	81.9
Check		91.2	59.8		161.5		167.5		183.5		186.5	
Minimum difference for significance at .05 level											45.4	

[1] Pounds active ingredient per acre.

Table 5.—Average number thrips on 10 plants and per cent control following treatments as indicated in experiment 5.

Insecticide and Rate[1]	Initial Population	Days After 1st Application				Days After 2nd Application			
		2		8		3		8	
		Number and Per Cent Control		Number and Per Cent Control		Number and Per Cent Control		Number and Per Cent Control	
Malathon .25	22.0	4.8	88.8	92.0	6.7	1.8	96.6	39.5	4.1
Systox .26	50.5	3.8	94.4	25.2	77.5	.8	98.5	22.2	71.3
Dieldrin .06	53.8	5.2	74.4	9.5	96.8	1.5	98.0	14.8	85.9
TM 269 .06	23.0	17.8	79.8	48.5	96.1	3.5	88.8	19.2	57.1

[1] Pounds active ingredient per acre.

compounds for thrips control: (1) octamethylpyrophosphoramide (OMPA), (2) systox,[3] (3) parathion and (4) toxaphene. The plats were arranged in randomized blocks. Each treatment and the check were replicated four times. Each plat was 14 rows wide and of sufficient length to make one-ninth of an acre. Spray applications were made on May 7 and May 18 at the average rates shown in table 4. Systox and OMPA were applied at the rate of 0.25 pound per acre on the first application while the rate was increased to 0.75 pound per acre for the second application. Infestation records were made on the second, seventh and tenth days following the first application and on the third, tenth, fifteenth and ninteenth days following the second application. The average populations during the treatment period are shown as seasonal averages in table 4.

Octamethylpyrophosphoramide failed to control thrips at 0.25 pound per acre but when the dosage was increased to 0.75 pound per acre a high degree of control was obtained, apparently from contact action. Systox was more effective for thrips control than OMPA.

The high dosages of OMPA and systox were used in an effort to obtain control from the systemic action of these compounds. Apparently thrips were not controlled in this manner. Parathion gave control comparable to that of the above named compounds at a much lower dosage. Toxaphene also gave effective control at about 0.75 pound per acre.

Experiment 5, shown in table 5 was for the purpose of comparing the toxicity of two compounds, malathon and TM 269 (a stereoisomer of dieldrin) to that of dieldrin and systox. The plats were one-tenth acre in size. Since the plats could not be replicated, the population data were obtained from four random points from each plat on each date. The data were not analyzed and the percentages of control obtained are considered only as indications of the toxicity of the compounds to thrips.

All the compounds gave good control of thrips immediately following each application. At a dosage of 0.25 pound per acre, malathon and systox gave poorer residual toxicity than dieldrin at 0.06 pound per acre. There was little difference in the toxicity of dieldrin and TM 269. However, the last population record indicated that dieldrin had a little longer residual toxicity than TM 269.

SUMMARY.—The following materials applied at comparatively low dosages gave good control of thrips for a period of at least 2 or 3 days: parathion, EPN, DDT, gamma BHC, gamma BHC-DDT, aldrin, dieldrin and toxaphene. Dieldrin, toxaphene, EPN and DDT were effective for a period of from 7 to 10 days and exhibited a longer residual toxicity than the other compounds.

In one experiment the dust and spray formulations of toxaphene, aldrin, and dieldrin were equally effective.

High dosages of systox and octamethylpyrophosphoramide were effective for immediate control of thrips but failed to show a long residual toxicity. Apparently these compounds did not control thrips by systemic action.

Malathon was not as effective as parathion and TM 269 was about as effective as dieldrin for thrips control.

[3] Diethoxythiophosphoric acid ester of 2-ethyl mercaptoethanol.

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Synergistic Effect of Piperonyl Butoxide with the Active Principles of Pyrethrum and with Allethrolone[1] Esters of Chrysanthemum Acids

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The synergistic effect of piperonyl butoxide when combined with pyrethrins has been shown to be of a high order in tests against house flies (Wachs 1947). However, although definite synergism has been demonstrated for combinations of allethrin[2] and piperonyl butoxide, these mixtures were found to be only about one-third as effective as the equivalent pyrethrins-piperonyl butoxide mixtures when tested on house flies (Jones *et al.* 1950).

In previous studies of the active components of natural pyrethrum alone on house flies it has been shown that the monocarboxylic or I type compounds demonstrated definite superiority over the dicarboxylic or II type compounds (Gersdorff 1947). Tests of allethrolone esterified with certain chrysanthemum acid isomers also showed a high order of insecticidal activity for the ester of the natural acid and indicated that the completely synthetic ester was almost twice as effective as pyrethrins (Gersdorff, 1949a and 1949b). An additional study of allethrolone esterified with the natural (*d-traus*) and synthetic (*dl-cis-trans*) acids on various species of insects showed a great deal of variation with the species used, but indicated a high insecticidal activity for both compounds (Elliott, *et al.* 1950). No studies have been reported of the synergistic effect of piperonyl butoxide with the individual active principles of pyrethrum or the allethrolone esters of certain chrysanthemum acid isomers.

The present study was undertaken to determine whether any one of the separated active components of pyrethrum might account for high synergistic activity of natural pyrethrins when combined with piperonyl butoxide. Also, as a possible clue to the lower degree of synergism displayed by allethrin with piperonyl butoxide as compared to pyrethrins plus this synergist, isomers of chrysanthemum monocarboxylic acid esterified with allethrolone were tested with piperonyl butoxide to determine if changes in optical or geometric configuration might result in changes in synergistic effect.

MATERIALS.—For the present study on the active components of pyrethrum a commercial 20 per cent pyrethrum extract in deodorized base oil was separated initially into a purified fraction and a residue. Nitromethane was used for this purpose according to the directions of Barthel *et al.* (1944). Three extractions with equal volumes of nitromethane removed about 97 per cent of the total pyrethrins. After solvent removal the concentrated extract was subjected to a differential separation into two main fractions through the use of acetic acid and petroleum ether (LaForge & Haller 1936). The first fraction analyzed about 43 per cent "pyrethrins I" and 14 per cent "pyrethrins II" and the second fraction analyzed 82 per cent "pyrethrins II" and 6 per cent "pyrethrins I." These two fractions were then converted to the

[1] Methylallylcyclopentenolone.

[2] Methylallylcyclopentenolone esterified with synthetic (*dl-cis-trans*) chrysanthemum monocarboxylic acid.

semicarbazones and separations made according to the method described by LaForge and his co-workers (1936). The resultant products were pure cinerin I, cinerin II, pyrethrin I, and pyrethrin II.

The purified extract, the residue remaining after purification, and the four active components were formulated on a weight-volume basis (mg. per 100 ml.) in deodorized kerosene, both alone and in combination with piperonyl butoxide at a one to ten ratio.

The separated pyrethrins and cinerins were recombined in the proportions in which they occur in natural extract. Generally, it is considered that the pyrethrins exist in about a 70 to 30 ratio to the cinerins, and it was on this basis that the studies involving these combinations were made.* Most pyrethrum extracts contain approximately equal quantities of I and II type compounds, so in such combinations a 50 to 50 ratio was used. These mixtures of pyrethrins and cinerins were combined with piperonyl butoxide at a ratio of one part of the mixture to ten parts of butoxide.

Esters of allethrolone were prepared with chrysanthemum dicarboxylic acid and four isomers of chrysanthemum monocarboxylic acid:

1. *dl-cis-trans*-Monocarboxylic acid. This was the completed synthetic chrysanthemum monocarboxylic acid. The product of the esterification of this material with allethrolone was allethrin.

2. *dl-trans*-Monocarboxylic acid. This acid was separated by the fractional crystallization of the synthetic *dl-cis-trans* acid according to the method of Campbell & Harper (1945).

3. *dl-cis*-Monocarboxylic acid. This acid also was prepared by the fractional crystallization of the synthetic *dl-cis-trans* acid.

4. *d-trans*-Monocarboxylic acid. The natural form of chrysanthemum monocarboxylic acid was derived from the hydrolysis of pyrethrum extract.

5. Natural chrysanthemum dicarboxylic acid. This acid also was derived from the hydrolysis of pyrethrum extract.

These esters were forumulated on a weight-volume basis in deodorized kerosene, alone and in combination with piperonyl butoxide at a ratio of one part of ester to ten parts of piperonyl butoxide.

Two standards were used for these studies, namely, pyrethrum extract and pyrethrum extract plus piperonyl butoxide at a one to ten ratio. The first was used in comparisons involving each of the pyrethrum components or the chrysanthemum acid esters when tested alone. The second was used when these components or esters were combined with piperonyl butoxide. The pyrethrum extract used in both standards contained a proportion of 54 parts of "pyrethrins I" and 46 parts of "pyrethrins II" and was formulated on the basis of the analyzed content of total pyrethrins.

Preliminary tests were made to determine the concentrations of each material alone and in combination with piperonyl butoxide which would give results in the 50 per cent mortality range. All of the materials were then tested at three different concentrations to give dosage-mortality curves intersecting the LD_{50} level.

PROCEDURE.—Evaluation of the effectiveness of these sprays was made on 3-day old laboratory-reared house flies, *Musca domestica* (L.), by the Campbell turntable method (1938) with certain modifications. Approximately 100 house flies were used per test. One-day mortality results were obtained with the natural pyrethrum components, both alone and in combination with piperonyl butoxide, as well as mixtures of the components combined with piperonyl butoxide, by means of three tests on each of two populations of flies. The mortality obtained with allethrolone esters alone and in combination with piperonyl butoxide was measured by two tests on each of two populations of flies.

The mortality results were plotted graphically on log-probability paper, and the LD_{50} concentration for each solution was estimated from the resulting fitted straight lines (Figs. 1 to 5). A figure representing the relative effectiveness of each of the sprays was obtained from the ratio of the LD_{50} of the standard pyrethrum extract to the LD_{50} values of the test solutions (Tables 1, 2, 3). In tests of the various materials with piperonyl butoxide the relative effectiveness was calculated from the LD_{50} values of these combinations compared with the LD_{50} of the pyrethrins-butoxide standard. Thus the standards always represented unity and a relative effectiveness value of less

* Private communication from Dr. F. B. LaForge.

Table 1.—Relative effectiveness of the separated active components of natural pyrethrum alone and with piperonyl butoxide. Turntable tests, house flies.

Material	Alone		With Piperonyl Butoxide (1 to 10 Ratio)		Relative Synergistic Effect
	LD_{50} (mg. per 100 ml.)	Relative Effectiveness	LD_{50} (mg. per 100 ml.)*	Relative Effectiveness	
Pyrethrins (from standard extract)	330	1.00	21.5	1.00	1.00
Pyrethrin I	190	1.74	21	1.02	0.59
Cinerin I	420	0.79	29	0.74	0.94
Pyrethrin II	490	0.67	54	0.40	0.60
Cinerin II	740	0.45	62	0.35	0.78

* Concentrations shown are for the pyrethrins from standard extract and the pyrethrum components only.

than one served as evidence that the test formula was less effective than the standard.

As a convenient means of expressing the relative degree of synergism shown by each material when combined with piperonyl butoxide, a value for the "relative synergistic effect" was determined. This figure was calculated by dividing the relative effectiveness of the test material in combination with piperonyl butoxide by the relative effectiveness of the test material alone. The resulting figure represents the relative degree of synergism exhibited by a material when combined with piperonyl butoxide at a one to ten ratio as compared with the pyrethrins standard when combined with piperonyl butoxide at the same ratio. It must be noted, however, that these are not absolute values and do not express the true effectiveness of the materials when combined with the synergist. For example, in table 1 the relative synergistic effect of pyrethrin I when combined with piperonyl butoxide is shown to be only 59 per cent as great as that of the standard pyrethrum extract, although pyrethrin I with piperonyl butoxide was equally as effective as the pyrethrins-butoxide standard. The values for relative synergistic effect then serve simply as relative terms to show what has been accomplished through the phenomenon of synergism by each material when combined with piperonyl butoxide in comparison with the synergistic effect shown by the standard pyrethrum extract plus butoxide.

Table 2.—Relative effectiveness of mixtures of the separated active components of natural pyrethrum with piperonyl butoxide. Turntable tests, house flies.

Material	With Piperonyl Butoxide (1 to 10 Ratio)	
	LD_{50} (mg. per 100 ml.)[1]	Relative Effectiveness
Pyrethrins (from standard extract)	22	1.00
70% PI+30% CI	23	0.96
50% PI+50% PII	25.5	0.86
35% PI+35% PII+ 15% CI+15% CII	28	0.79
50% CI+50% CII	31	0.71
70% PII+30% CII	66	0.33

[1] Concentrations shown are for pyrethrins from standard extract and the mixtures of pyrethrum components only.

Results.—Preliminary tests of the highly purified pyrethrum extract and the residue of waxes remaining after this purification confirmed the fact that the synergistic factor in the extract was present only in the highly purified pyrethrins fraction. This material gave mortality results comparable to those obtained with the standard pyrethrum extract when combined with piperonyl butoxide, while the residue of waxes gave only the effectiveness expected from the 2 to 3 per cent pyrethrins remaining after purification.

The separated active components of pyrethrum, when tested alone in comparison with the standard, showed the same general order of relative effectiveness listed by Gersdorff (1947), although the values for the I type compounds were slightly lower (Table 1). This same order of relative effectiveness was demonstrated in combinations of the components with piperonyl butoxide. In these tests pyrethrin I was superior to the standard pyrethrum extract when used alone; however, when used in combination with piperonyl butoxide, it was equal to the pyrethrins-butoxide standard in effectiveness. When tested alone and with

Table 3.—Relative effectiveness of allethrolone esters of various chrysanthemum acids alone and with piperonyl butoxide. Turntable tests, house flies.

MATERIAL	ALONE		WITH PIPERONYL BUTOXIDE (1 TO 10 RATIO)		RELATIVE SYNERGISTIC EFFECT
	LD_{50} (mg. per 100 ml.)	Relative Effectiveness	LD_{50} (mg. per 100 ml.)[2]	Relative Effectiveness	
Pyrethrins (from standard extract)	(350)[1]	1.00	17	1.00	1.00
dl-cis-trans mono-acid[3] ester (Allethrin)	162	2.16	55	0.31	0.14
dl-trans mono-aid ester	135	2.59	60	0.28	0.11
dl-cis mono-acid ester	325	1.08	105	0.16	0.15
d-trans (natural) mono-acid ester	85	4.12	30	0.57	0.14
dicarboxylic (natural acid ester	465	0.75	108	0.16	0.21

[1] Tests of pyrethrins from standard extract alone were made concurrently but not simultaneously with the other tests.
[2] Concentrations shown are for the pyrethrins from standard extract and the allethrolone esters only.
[3] Chrysanthemum monocarboxylic acid.

piperonyl butoxide, cinerin I was approximately 75 per cent as effective as the standards, and the effectiveness of both pyrethrin II and cinerin II was quite low in comparison with the standards.

When mixtures of the separated pyrethrum components were tested in combination with piperonyl butoxide (Table 2), the relative effectiveness values at the LD_{50} level showed that the I type compounds, combined in a 70 to 30 ratio, were almsot as effective as the standard. The II type compounds, combined in the same ratio, were only one-third as effective as the standard. Mixtures of I and II type compounds in a 50 to 50 ratio were inferior to the standard, and the combination of all the pyrethrum components in the ratio believed to be the same as that found in natural pyrethrum extract also was less effective than the standard.

In the study of esters of allethrolone with isomers of chrysanthemum monocarboxylic acid (Table 3), the *dl-cis-trans* monocarboxylic acid ester (allethrin) and the *dl-trans* mono-acid ester were both more than twice as effective as the standard extract when compared alone at the LD_{50} level. The natural *d-trans* mono-acid ester was over four times as effective as the standard, and the *dl-cis* mono-acid ester was approximately equal to it. The natural dicarboxylic acid ester was only about 75 per cent as effective as the standard at the LD_{50} level.

It is noteworthy that the ester of the *dl-cis* mono-acid was shown to be definitely less effective than that of the *dl-trans* mono-acid. This difference in the toxicity of allethrolone esterified with the *dl-cis* mono-acid and allethrolone esterified with the *dl-trans* form also has been found in recent studies by Elliott (1951) and Gersdorff & Mitlin (1952). In addition, it may be assumed, from a comparison of the results obtained with the esters of the *dl-trans* acid and the *d-trans* natural acid, that the ester of the *l-trans* acid would have a very low order of effectiveness. This has been confirmed by the recent work of Elliott (1951) and LaForge and his co-workers (1952).

In combination with piperonyl butoxide these esters among themselves retained the same general order of effectiveness, but all were much lower in effectiveness

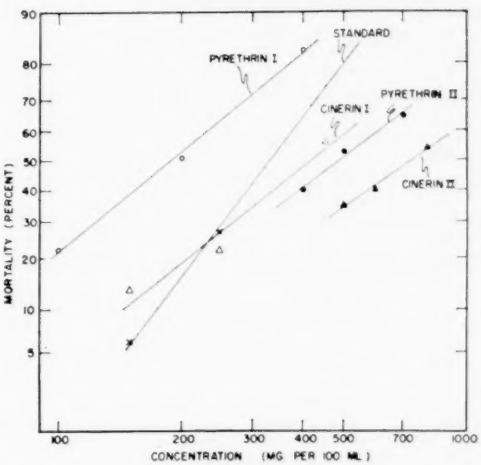

FIG. 1.—Dosage-mortality comparisons of the separated active components of natural pyrethrum, turntable tests; house flies.

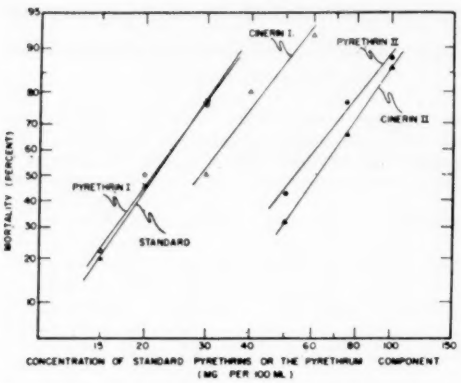

FIG. 2.—Dosage-mortality comparisons of the separated active components of natural pyrethrum, in combination with piperonyl butoxide at a 1 to 10 ratio, turntable tests; house flies.

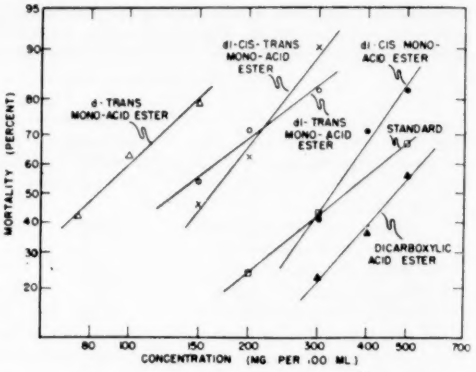

FIG. 4.—Dosage-mortality comparisons of allethrolone esters of chrysanthemum monocarboxylic acid isomers and of chrysanthemum dicarboxylic acid, turntable tests; house flies.

than the pyrethrins-butoxide standard (Table 3).

DISCUSSION.—The synergistic effect of piperonyl butoxide, when combined with the individual active components of pyrethrum, is shown by the values for relative synergistic effect given in the final column of table 1. On the basis of these figures inerin I and cinerin II have a somewhat greater relative degree of synergism with piperonyl butoxide than do pyrethrin I and pyrethrin II. It may be concluded from these results that no one of the components contributed the major portion of the synergism displayed by piperonyl butoxide with pyrethrins, since none of the components showed greater synergistic activity than the standard pyrethrum extract.

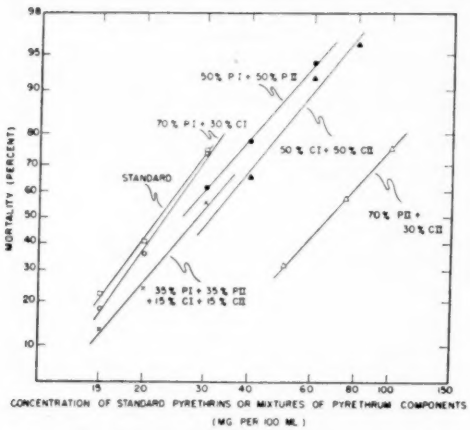
50% PI + 50% PII
70% PI + 30% CI
50% CI + 50% CII
STANDARD
70% PII + 30% CII
35% PI + 35% PII + 15% CI + 15% CII
MORTALITY (PERCENT)
CONCENTRATION OF STANDARD PYRETHRINS OR MIXTURES OF PYRETHRUM COMPONENTS
(MG PER 100 ML)

FIG. 3.—Dosage-mortality comparisons of mixtures of the separated active components of natural pyrethrum, in combination with piperonyl butoxide at a 1 to 10 ratio, turntable tests; house flies.

The tests on mixtures of the pyrethrum components with piperonyl butoxide also demonstrated that no mixture of the components used in this study would produce synergistic effect superior to that obtained with the standard pyrethrum extract (Table 2).

Although the esters of allethrolone with isomers of chrysanthemum monocarboxylic acid and with chrysanthemum dicarboxylic acid exhibited marked differences in effectiveness, both alone and when combined with piperonyl butoxide, all of them showed about the same relative degree of synergistic activity, and this synergistic effect was much less than that between natural pyrethrins and piperonyl butoxide, as shown in the final column of Table 3. It is evident from these results that both optical and geomet-

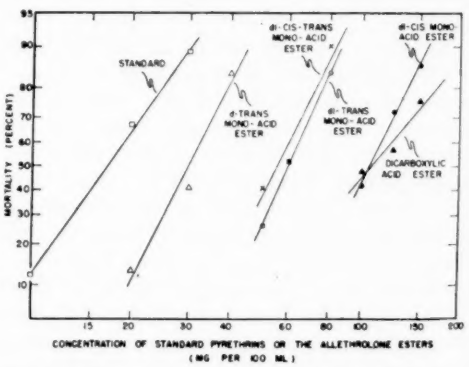

FIG. 5.—Dosage-mortality comparisons of allethrolone esters of chrysanthemum monocarboxylic acid isomers and of chrysanthemum dicarboxylic acid, each in combination with piperonyl butoxide at a 1:10 ratio, turntable tests; house flies.

ric isomerism in the acid portion of the molecule influence the insecticidal effectiveness of allethrolone esters of chrysanthemum monocarboxylic acid, alone as well as in combination with piperonyl butoxide, but have little effect on comparative synergistic activity.

SUMMARY.—The synergistic effect of piperonyl butoxide with the separated active components of pyrethrum and with allethrolone esters of chrysanthemum acids was determined in tests on house flies by the turntable method.

By the use of a value representing relative synergistic effect it was shown that the cinerins exhibited a somewhat greater degree of synergism in combination with piperonyl butoxide than did the pyrethrins, although pyrethrin I and II showed superior effectiveness to the corresponding cinerins both alone and in combination with piperonyl butoxide.

Since none of the separated active components of pyrethrum showed greater synergistic activity than the standard pyrethrum extract, it may be concluded that no one of the components of pyrethrum contributed the major portion of the synergism found with combinations of piperonyl butoxide and pyrethrins.

Although optical and geometric isomerism in the acid portion of the molecule have a marked influence on the insecticidal effectiveness of allethrolone esters of chrysanthemum monocarboxylic acid, when used alone or in combination with piperonyl butoxide, they have little effect on comparative synergistic activity.

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North Central States Branch A.A.E.E. to hold its 1953 meeting at the Hotel Statler, St. Louis, Missouri, March 19 and 20. The Proceedings of the 1952 meeting held last March at St. Paul, Minnesota are available for $2.50 from J. W. Apple, 104 King Hall, University of Wisconsin, Madison, Wisconsin.

Controlling Cherry Fruitworm in Colorado[1]

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The necessity of controlling "cherry worms" became evident in 1945, when the armed forces refused the northern Colorado crop of Montmorency cherries, because of worm-injured fruits. In 1946, experiments were started in orchards of cooperating growers, and have been continued through 1950. The results of these tests have been the basis for annual spray recommendations.

Preliminary work in 1945 indicated that the cherry fruitworm *Grapholitha packardi* (Zell.), the lesser appleworm, *Grapholitha prunivora* (Walsh), mineola moth *Mineola scitulella* Hulst., and the cherry curculio, *Tachypterellus consors cerasi* List, were all implicated in the cause of wormy cherries. Many of the larvae taken were not full grown and were determined as belonging to the family Phycitidae (probably the larvae of the mineola moth). The life history, control, and injury to cherries by the cherry curculio have been reported by List (1932). Only a trace of curculio injury has occurred in widely separated orchards the past 5 years. In 1946 and 1947 only an occasional mineola moth larva[2] was taken on cherries, however the number increased slightly in 1948 and 1949. No larvae of the lesser appleworm have been found since 1945. The cherry fruitworm has been the important insect causing wormy cherries.

The cherry fruitworm is not entirely new as a cherry pest in Colorado. Attention was first called to it in 1914 by a grower of Masonville in the foothills west of Fort Collins. He stated he first noted what he thought was the same larvae in the fruit in 1898. As the orchard was one of the first planted in northern Colorado, this might indicate that the species occurred on the wild chokecherry, *Prunus virginiana* L., which is abundant in the foothills, before the cultivated cherry was introduced. Fruit from an orchard just west of Fort Collins was refused by a processor in 1915 and again in 1922 on account of infestations by this species. Records taken from 1925 to 1929 while work was being done on the cherry curculio showed as high as 3 per cent of the fruit attacked by the fruitworm. In 1929 the fruit from an orchard of Rocky Ford, Otero County, Colorado, was refused by the processors because of worms. The insect is known to occur in the cherry orchards of Fremont County.

Cherry fruitworm losses to sour cherries on Vancouver Island and the lower British Columbia mainland have been reported by Downes (1928) (1931). Breakey & Webster (1938) report this insect as occurring in western Washington. Lipman (1936) and others have reported the cherry fruitworm as a pest on blueberries in New Jersey. According to Richardson (1944) the cherry fruitworm was first found in Iowa in 1944. Fluke (1951) reported the cherry fruitworm occurring in Wisconsin.

DESCRIPTION AND BIOLOGY. — The adult of the cherry fruitworm is a small dark gray moth 0.25 to 0.375 inch across the expanded wings. Eggs are 0.02 inch in diameter, circular in outline, flattened, and opalescent. The larvae when first hatched are 0.25 inch in length, white in color with a black head. Later the larvae take on a pink tint and grow to nearly 0.375 inch in length. The brown pupae are about 0.19 inch in length. Drawings of the different stages are shown in figure 1.

The moths appear in the orchards about the first of June, with the peak of moth emergence around June 15, although this time varies somewhat according to weather conditions. The eggs are deposited on the cherries, often in the suture or in any rough spot. Sometimes they may be placed around the stem or on the stem close to the fruit. Under laboratory conditions eggs may be placed on the leaves, but in the field, those observed have always been on the cherry or on the stem. In heavily infested orchards, eggs are readily found during the later half of June.

A few eggs observed under laboratory conditions hatched in seven days. After hatching, the larvae may crawl around on the fruit for several hours. Entrance holes are usually made in a depression or rough spot on the cherry, or they may enter at the stem end. The entrance holes are very minute and usually have a small

[1] Scientific Journal Series No. 345 Colo. Agr. Expt. Station.
[2] Determined by H. W. Capp, Division of Insect Identification, U.S.D.A.

amount of frass present around the opening. A hand lens is necessary for the positive identification of these small entrance holes. The larvae tunnel through fruit around the stone, maturing in about three weeks. When full grown the larvae leave the fruits, making large exit holes, and seek hibernal quarters. The larvae find suitable shelter in the pruned stubs of dead twigs, under the bark, in the stems of weeds and grasses or in the ground. The hibernating larvae are readily found in the pruned stubs where they tunnel the pith to a depth of 0.5 to 1.25 inches deep. After lining the excavated cavity with silk and plugging the opening, they remain in these quarters until the following May, at which time they pupate. The average pupal stage is 29 days. Ordinarily there is one generation a year. In 1946 a few second generation moths were reared from larvae collected in June and three larvae were taken in cherries on September 10, thus indicating that a partial second generation may occur. The first appearance of the moths, as determined by using oriental fruit moth bait traps, is near the first of June. In 1947 and 1949 the peak of moth emergence was June 15, in 1948 it occurred on June 7. In 1946 one moth was captured in a cherry orchard on May 17 and moths have been taken in bait traps as late as July 7.

INJURY.—Injured cherries that are deformed and discolored are easily detected. However, a few normal appearing cherries are found to be wormy when cut open. In an average season, practically all the worms have left the fruit by the time the cherries are harvested the latter half of July. In 1946 and 1947, very few of the worm injured cherries fell from the trees, while in 1948 fully 50 per cent of the injured fruit had dropped by harvest time. Infestations of 2 and 3 per cent are common, a few have been 6 to 8 per cent. In a few cases where light crops occurred, infestations have gone as high as 30 and 60 per cent. The Montmorency, Early Richmond and English Morello appear to be equally infested.

When the cherries are received at the "docks" of the processing plants, they are placed in tanks of water where most of the worm injured cherries will float. However, a few will sink with the sound cherries and it is practically impossible to keep them out of the processed pack.

CONTROL EXPERIMENTS.—Insecticides tested in 1946 in 2 and 3 applications for the control of this insect were lead arsenate 3 pounds, cryolite 3 pounds, rotenone (4.75 per cent) 2.5 pounds, nicotine alkaloid (14 per cent) 2 pounds with 1 quart summer oil, and DDT 1 pound (2 lbs. 50 per cent wettable), each with 100 gallons of water. The experimental design was a 6 by 6 latin square with 2 and 4 trees per plot. Applications were

Table 1.—Results of tests of insecticides against the cherry fruitworm, Orchard No. 1, Fort Collins, 1948.

TREATMENT (MATERIAL USED FOR 100 GALLONS)	ADJUSTED RANK	COMBINED 2 AND 3 APPLICATIONS ADJUSTED MEAN WORMY FRUITS PER TREATMENT	2 APPLICATIONS		3 APPLICATIONS	
			Per Cent Wormy	(Rank)	Per Cent Wormy	(Rank)
Parathion 2 lbs. 25% W	1	0.23	0.03	(2)	0.008	(1)
Methoxychlor 2 lbs. 50% W	2	0.75	0.01	(1)	0.040	(2)
DDT 1½ lbs. 50% W	3	1.13	0.06	(4)	0.086	(3)
TDE (DDD) 2 lbs. 50% W	4	1.23	0.05	(3)	0.114	(4)
Nicotine alkaloid 2 lbs summer oil 1 qt.	5	2.41	0.19	(5)	0.132	(5)
Rotenone 2½ lbs. synergized rotenone 941 cc.	6	4.64	0.28	(6)	0.285	(8)
Chlordane 2 lbs. 50% W	7	4.99	0.37	(7)	0.295	(9)
Lead arsenate 3 lbs.	8	5.06	0.41	(9)	0.280	(7)
Rotenone 2½ lbs. (4.75%)	9	5.27	0.41	(10)	0.250	(6)
Toxaphene 4 lbs. 25% W	10	5.49	0.39	(8)	0.341	(10)
Check untreated	11	11.95	0.62	(11)	1.084	(11)
Significance 5% point		2.41				
1% point		3.18				

Data based on 228,106 fruits.

made May 30, June 13, and June 27. Each application was made with a spray gun with 300-350 pounds pressure, the operator encircling the tree. Approximately 1.5 gallons of spray per tree per application was used. One orchard selected and sprayed had been reported as being 6 or 7 per cent wormy in 1945. At harvest time the check showed so few worm injured cherries (.015 per cent) that the sprayed plots were not sampled. In the second orchard late freezes had reduced the crop to about 20 per cent. In this orchard all the cherries (169,658 fruits) on the experimental trees were picked, examined, and the data analyzed.

DDT gave the best control and was significantly better than the untreated check and most of the other materials used. There was a significant increase in the injury from the two spotted mite on the trees sprayed with DDT.

Residue analyses were made on cherries from the two orchards in which the tests were conducted. The residue on one of the samples of cherries sprayed with 3 applications of DDT exceeded the suggested tolerance of 7 ppm. The recommendation for the 1947 season was the use of DDT at the rate of 0.75 pound actual (1.5 pounds 50 per cent W) to 100 gallons of water.

Tests during the 1947 season were made in an orchard west of Fort Collins. Late freezes reduced the crop to less than one per cent. Spray plots each consisting of 12 trees were arranged in randomized blocks for seven treatments with six replications. All the cherries on the sprayed trees were picked and examined for worm injury. Mathematical analysis showed no significant differences from the various treatments. DDT gave the lowest per cent of wormy fruit, although its use would not be practical under the conditions tested.

A paired plot test with methoxychlor, not included in the materials tested in the randomized blocks showed very promising resuts. Two applications of the methoxychlor (2 lbs. 50 per cent W/100) gave 3.82 per cent wormy fruit compared with 23.65 per cent in the check. Three applications gave 1.98 per cent wormy fruit as compared with 24.18 on the untreated.

Tests in 1948 were again conducted in the same orchard used in 1947. Plots of 12 trees were arranged in randomized blocks for 11 treatments with seven replications. The crop was about 25 per cent normal. One-fourth tree in each plot was harvested and examined for wormy cherries. The results of the test are shown in table 1.

The results from table 1 show that all the insecticides used significantly reduced the number of wormy fruits from that of the untreated check. Parathion, methoxychlor, DDT, and TDE were equal and very significantly better than the other insecticides used with the exception of nicotine alkaloid with summer oil.

In a paired plot test in orchard No. 1, one application of methoxychor at 4 pounds per 100 gallons compared on the per cent wormy bases, appears to be equal to the two and three applications of the four best materials. In orchard No. 2, paired plot tests indicate that methoxychlor at 2 and 4 pounds is considerably better than DDT. The results of these tests are shown in table 2.

Table 2.—Results of tests of insecticides against the cherry fruitworm. Paired plot tests orchard No. 1, Fort Collins, 1948, one application.

	Total Fruits	Fruits Wormy	Per Cent Wormy
Methoxychlor 4 lbs. 50% W/100	4151	2	0.04
Untreated check	3970	24	0.60
Orchard No. 2—Two Applications			
Methoxychlor 4 lbs. 50% W/100	2000	16	0.80
Methoxychlor 2 lbs. 50% W/100	2000	27	1.35
DDT 2 lbs. 50% W/150 gals.	2000	126	6.30

A small orchard near Loveland had been sprayed three times with a compressed air sprayer using 60 pounds pressure and a garden hose nozzle. Even though the recommended strength of DDT had been used, by June 15 the cherries were about 20 per cent wormy. On June 17 the fourth application of spray was made to part of the orchard using the compressed air sprayer with DDT 1.5 lbs. 50 per cent W and methoxychlor 2 lbs. 50 per cent W. The rest of the orchard was sprayed using the same materials applied with a power sprayer at 400 pounds pressure and a 4 disc spray broom. A week later samples taken in the orchard showed a difference in per cent of wormy fruit in favor of the power sprayer of 5.6 with the methoxychlor and 8.5 with the DDT.

Residue analysis,[3] orchard No. 1,

[3] L. H. Chernoff, Food and Drug Administration.

Table 3.—Results of tests against the cherry fruitworm, orchard No. 1, Loveland, Colorado, 1949.

TREATMENT (MATERIAL USED/100 GALLONS)	APPLICATIONS	ORIGINAL RANK	ADJUSTED MEAN WORMY	ADJUSTED RANK	PER CENT WORMY
Parathion 2# 15% W	3	1	13.71	1	0.95
Parathion 2# 15% W	2	2	24.98	2	1.82
Methoxychlor 2# 50% W	2	3	87.39	3	5.99
Methoxychlor 2# 50% W	3	4	103.92	4	6.47
Check	—	5	246.33	5	16.01
Significance 5% point			46.07		
1% point			62.83		

Spray dates—1st application June 1, 1949.
2nd application June 15.
3rd application June 27.
Approximately 2 gallons of spray per tree per application used.
Residue analysis by Food and Drug Administration, Denver, Colorado. Lewis H. Chernoff, Chief Chemist. Samples harvested July 18, 1949. Orchard No. 1.

	2 Applications	*3 Applications*
	ppm.	*ppm.*
Parathion 2# 15% W/100	0.002	0.004
Methoxychlor 2# 50% W/100	1.3	2.5

showed 2.1 ppm for 2 applications, and 5.3 ppm for 3 applications of DDT. Cherries sprayed with 2 applications of lead arsenate showed 6.5 ppm of lead and 3.6 ppm of arsenic. Three applications of lead arsenate gave residues of 22.2 ppm of lead and 12.7 ppm of arsenic, both of which are over the tolerance permitted. The parathion showed 0.10 ppm and the methoxychlor, 2.0 ppm.

The oral toxicity to vertebrates of the four materials giving the best control are rated by Lehman (1948) as DDT 1, parathion 70, TDE one-tenth, and methoxychlor one-twenty-fourth. Parathion should be used 30 days before harvest. Because of its low toxicity to vertebrates, methoxychlor (2 lbs. 50 per cent W) was the first choice of materials to be recommended for the control of the cherry fruitworm for the 1949 season. DDT (1.5 lbs. 50 per cent W) was the second recommendation. As the Food and Drug Administration has suggested a tentative DDT residue tolerance of 5 ppm on all foods, only two applications of DDT were recommended for the 1949 season.

During the 1948 season, larvae collected were about one per cent parasitized. Most of the parasites were determined[4] as *Ascogaster quadridentata* Wesm. and a few as *Bassus* sp. Moths from bait traps and those that were reared were determined[5] as the cherry fruitworm. Larvae sent in for identification were mostly the cherry fruitworm, a few were the mineola moth.

In 1949 tests were carried out at Loveland, Colorado, in orchard No. 1 and

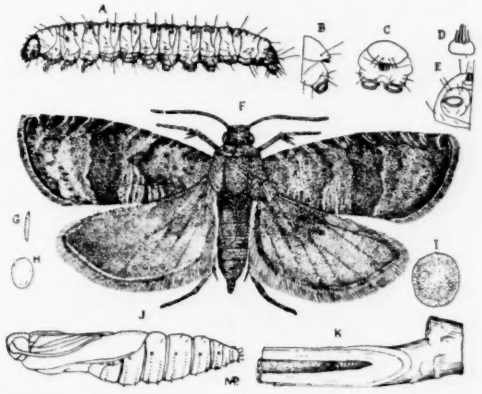

FIG. 1.—A—Larva; B, C, D, E—Comb-like plate on posterior end of larva; F—Moth; G, H, I—Egg; J—Pupa; K—Hibernating larva. A, ×4; B, C, E, F, G, H, ×6; D, I, ×13; J, ×8; K, ×1 2/3.

orchard No. 2, both of which were known to be infested with the cherry fruitworm the preceding season. A commercial sprayer made the applications in orchard No. 1, the operator encircling the tree with a spray gun at 350 pounds pressure. Applications were made in orchard No. 2 in a similar manner except the pressure varied from 350 to 400 pounds. Seven inches of rain the first part of June interfered with the spray application. The results in orchard No. 1 are shown in table 3, and in orchard No. 2 in table 4.

DDT, the recommended spray for the past three years, was not significantly better than the untreated check. Combin-

[4] C. F. W. Muesebeck, Division of Insect Identification, B.E.P.Q., U.S.D.A.
[5] Carl Heinrich, Division of Insect Identification, B.E.P.Q., U.S.D.A.

Table 4.—Results of tests against the cherry fruitworm, orchard No. 2, Loveland, 1949.

Treatment (Material Used for 100 Gallons)	Adjusted Rank	Combined 2 and 3 Applications Adjusted Mean Wormy Fruits	Wormy-Fruits Mean	Original Rank
Parathion 2# 15% W	1	4.70	8.50	2
Parathion 3# 15% W	2	10.91	8.25	1
Parathion 1# 15% W	3	12.77	12.08	3
Methoxychlor 1# 50% W	4	31.85	38.25	5
Methoxychlor 2# 50% W	5	33.59	27.00	4
Methoxychlor 2# 50% W (Nicotine sulfate and oil in 2nd & 3rd)	6	42.71	39.83	6
Nicotine sulfate 1/800+1% Summer oil	7	46.74	50.08	7
DDT 2# 50% W	8	117.44	117.17	8
Check	9	166.79	166.33	9
Significance 5% point		53.39		
1% point		71.44		

Spray dates, 1st application June 2–3.
2nd application June 16–20.
3rd application June 27–28.
Approximately 2 gallons spray per tree per application used.
Residue samples, orchard No. 2, Loveland, 1949, harvested July 18. Analysis by Food and Drug Administration, Denver, Colorado. Lewis H. Chernoff, Chief Chemist.

	2 Applications ppm.	*3 Applications* ppm.
Parathion 1 lb. 15%W/100 gals.	0.004	0.004
Parathion 2 lbs. 15%W/100 gals.	0.002	0.007
Parathion 3 lbs. 15%W/100 gals.	0.004	0.007
DDT 1½ lbs. 50%W/100 gals.	0.3	3.2
Methoxychlor 1 lb. 50%W/100 gals.	1.6	2.6
Methoxychlor 2 lbs. 50%W/100 gals.	1.6	2.6
Methoxychlor 2 lbs.+Nicotine sulfate+oil	3.3	2.6
Methoxychlor 4 lbs. 50%W/100 gals.	3.0	0.6*

* 1 application.

ing nicotine sulfate and oil with the methoxychlor did not give an increase in cherry fruitworm control. Very good cherry fruitworm control was obtained with parathion and methoxychlor when the untreated check did not give over 9.5 per cent wormy fruit. In orchard No. 1, where the untreated fruits ran 16 per cent wormy, these materials did not give adequate protection.

John R. Stuntz, entomological scout, found the chokecherry *Prunus virginiana* L. to be a native host of the cherry fruitworm. The small size of the chokescherry usually necessitates the use of two cherries tied together with silk to mature one worm. The appearance of the cherry fruitworms on the chokecherries was about a month later than on the cultivated cherries.

In 1950 tests were again conducted in orchard No. 2, Loveland, using randomized blocks with 8 treatments and 6 replications. Combining parathion 2 pounds 15%W with methoxychlor 2 pounds 50%W, and the second combination at one half of these amounts, did not give as good control as parathion alone. Aldrin 8 ounces, lindane 1 pound 25%W, and dieldrin 4 ounces, each in 100 gallons of water were significantly inferior to parathion or methoxychlor.

SUMMARY.—The cherry fruitworm has occurred in Colorado for at least 35 years. This insect was established as an important sour cherry pest in 1945 when the entire northern Colorado crop was refused by the armed forces. As there is no tolerance for worms or worm injured cherries permitted in the consumer pack for interstate commerce, nothing short of 100 per cent control measures will be satisfactory. Tests for five years based on more than one million fruits show parathion and methoxychlor as the most promising control insecticides.

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Mosquito-Repellent Mixtures[1,2]

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Since 1942 several thousand chemicals have been tested in the laboratory and in the field to determine their value repelling mosquitoes and other biting insects. The preliminary evaluation was done in the laboratory against *Aëdes aegypti* (L.) and *Anopheles quadrimaculatus* Say, following a modification of the method developed by Granett (1940). The results with 59 of the better compounds were reported by Travis *et al.* (1949). Most of them were tested by the U. S. Food and Drug Administration for toxicity when applied to the skin, and 14 were indicated safe for use (Draize *et al.* 1948).

Field experience against a variety of species has demonstrated that mixtures of several good repellents are effective against a wider range of species and on more individuals than any one repellent used alone. For this reason a mixture (M-250) containing six parts of dimethyl phthalate, two parts of 2-ethyl-1,3-hexanediol (*Repellent 6–12*) and two parts of *Indalone*, was adopted for use in World War II and is still the standard repellent of the armed forces. Although this mixture has proved very effective against mosquitoes all over the world, the search has continued for new repellents, and for mixtures with a higher general effectiveness than M-250.

During the last few years particular attention has been given to the formulation and testing of various combinations of the 14 highly effective repellents that have been declared safe for application to the skin. Dimethyl phthalate has been included in most of the mixtures because of its outstanding superiority against *Anopheles quadrimaculatus*. The effectiveness of mixtures containing six parts of dimethyl phthalate, two parts of *Indalone*, and two parts of each of the 12 other repellents against *Aëdes aegypti* and several species of Alaskan *Aëdes* were recently reported by Travis & Smith (1951) and by Applewhite & Smith (1950). In these tests, mixtures containing dimethyl carbate (dimethyl ester of *cis*-bicyclo[2.2.1]-5-heptene-2,3-dicarboxylic acid acid) and propyl *N,N*-diethylsuccinamate in place of 2-ethyl-1,3-hexanediol were among the most effective against all species. Results of recent tests with a group of promising new mixtures are presented in this paper.

METHODS AND MATERIALS.—Tests against *Aëdes aegypti* and *Anopheles quadrimaculatus* were conducted in the laboratory, whereas those against the salt-marsh mosquitoes *Aëdes taeniorhynchus* (Wied.) and *A. sollicitans* (Walk.) were conducted in the field. In all tests 1 cc. of repellent was spread evenly over the forearm of a subject, and compared directly with a standard repellent, usually M-250, on the other arm. In the laboratory tests each arm was exposed for 3 minutes every 30 minutes to caged mosquitoes, whereas in the field both arms were exposed continuously to natural infestations. Effectiveness was usually based on complete protection, or the time between treatment and the first confirmed bite (a bite followed by another within 30 minutes). In some tests the partial protection provided by different repellents was also compared, based on the average time to the first six bites. The

[1] Presented at the meeting of the American Association of Economic Entomologists, Cincinnati, Ohio, Dec. 10–13, 1951.
[2] This work was conducted under funds allotted by the Department of the Army to the Bureau of Entomology and Plant Quarantine.
[3] Now Captain, MSC, USA.
[4] The writers acknowledge the assistance of W. V. King and W. C. McDuffie, under whose supervision this work was done and also of Nelson Smith, R. Pratt, R. Sutton, and R. Graves.

relative effectiveness was expressed as a ratio obtained by dividing the protection time of the experimental repellent by the protection time of the standard.

Some tests were continued until both materials failed, whereas others were discontinued when one material had shown definite superiority by remaining effective 30, 60, or 90 minutes longer than the other. When the protection periods for certain repellents were exceptionally long, the repellents were sometimes evaluated as 25- or 50-per cent solutions in ethyl alcohol, previous studies having shown that dilution reduced the protection times of repellents proportionately.

In each series of tests the comparison between two mixtures was usually based on three replicate tests on different individuals.

The mixtures used in these experiments consisted of various combinations of five outstanding repellents that had passed toxicological tests and two that require further toxicological tests. For the sake of brevity they are hereafter designated by mixture numbers. The formula of each mixture is as follows:

M-250 —Dimethyl phthalate 6 parts, 2-ethyl-1,3-hexanediol 2 parts, *Indalone* 2 parts.

M-526 —Dimethyl phthalate 6 parts, 2-ethyl-1,3-hexanediol 4 parts.

M-1616—Dimethyl phthalate 6 parts, dimethyl carbate 2 parts, *Indalone* 2 parts.

M-1806—Dimethyl phthalate 6 parts, propyl *N,N*-diethylsuccinamate 2 parts, *Indalone* 2 parts.

M-2015—Dimethyl phthalate 6 parts, propyl *N,N*-diethylsuccinamate 4 parts, 2-ethyl-1,3-hexanediol 2 parts, *Indalone* 2 parts.

M-2016—Dimethyl carbate 6 parts, 2-ethyl-1,3-hexanediol 2 parts, *Indalone* 2 parts.

M-2019—Dimethyl carbate 4 parts, 2-ethyl-1,3-hexanediol 3 parts, propyl *N,N*-diethylsuccinamate 3 parts.

M-2020—Dimethyl phthalate 4 parts, 2-ethyl-1,3-hexanediol 3 parts, dimethyl carbate 3 parts.

M-2042—2-Ethyl-1,3-hexanediol 4 parts, propyl *N,N*-diethylsuccinamate 3 parts, *o*-chloro-*N,N*-diethylbenzamide 3 parts.

M-2043—Dimethyl phthalate 4 parts, 2-ethyl-1,3-hexanediol 3 parts, propyl *N,N*-diethylsuccinamate 3 parts.

M-2044—Dimethyl phthalate 4 parts, 2-ethyl-1,3-hexanediol 3 parts, *o*-chloro-*N,N*-diethylbenzamide 3 parts.

M-2045—Dimethyl phthalate 4 parts, 2-ethyl-1,3-hexanediol 3 parts, OM-323 3 parts.

M-2046—Dimethyl phthalate 5 parts, *o*-chloro-*N,N*-diethylbenzamide 5 parts.

M-2047—2-Ethyl-1,3-hexanediol 5 parts, *o*-chloro-*N,N*-diethylbenzamide 5 parts.

M-2048—Propyl *N,N*-diethylsuccinamate 5 parts *o*-chloro-*N,N*-diethylbenzamide 5 parts.

OM-321 —*o*-Chloro-*N,N*-diethylbenzamide 8 parts isopropyl alcohol 2 parts.

OM-322 —2-Methoxyethyl ester of *N*-ethyl-*o*-methylcarbanilic acid 8 parts, isopropyl alcohol 2 parts.

OM-323 —2-Chloro-*N,N*-diethylbenzamide 4 parts, 2-methoxyethyl ester of *N*-ethyl-*o*-methylcarbanilic acid 4 parts, isopropyl alcohol 2 parts.

RESULTS.—*Laboratory tests against Aëdes aegypti.*—Three series of tests were conducted against *Aëdes aegypti*, using M-250 as a standard of comparison. The first series provided an initial evaluation of samples of two compounds received from a commercial source. The second series of tests was made with various mixtures of five outstanding repellents and one of the commercial samples from the first series. In this series protection periods were so long that more than half the tests were terminated after 7 or 8 hours, when only the standard repellent had failed. Another series of tests was therefore conducted with the same mixtures, using 50-per cent solutions in ethyl alcohol. The results obtained in the first and last series are presented in table 1.

Table 1.—Relative effectiveness of various repellent mixtures in paired tests as skin applications against *Aëdes aegypti*. Repellent M-250 used as standard.

Experimental Repellent Number	Number of Tests	Minutes to First Bite		Ratio
		Experimental Repellent	Standard Repellent	
Full-strength materials				
OM-321	4	310	343+	<0.90
OM-322	2	138	210+	< .66
OM-323	4	433	282	1.54
G-18539	3	334	355+	< .94
G-19027	2	121	180+	< .67
50-Per-cent solutions				
M-526	3	212	141	1.50
M-1616	3	95	190	.50
M-2015	3	150	163	.92
M-2020	3	274	209	1.31
M-2042	3	277+	125	>2.22
M-2043	3	315	176	1.79
M-2044	3	381+	224	>1.70
M-2045	3	236	112	2.11
M-2046	3	377+	122	>3.09
M-2047	3	317+	164	>1.93
M-2048	3	361	87	4.15

One of the commercial samples, *o*-chloro-*N,N*-diethylbenzamide, was almost equal to M-250 in effectiveness, and so was the 80-per cent solution of the same compound, OM-321. In two of three tests, these materials failed at the same

time as M-250, whereas in the other M-250 was effective for an additional hour, after which exposures were discontinued. The other commercial sample, 2-methoxyethyl ester of *N*-ethyl-*o*-methyl carbanilic acid, and OM-322, which contained 80 per cent of the same material, were much less effective than M-250, but OM-323, which contained a mixture of *o*-chloro-*N*,*N*-diethylbenzamide and 2-methoxyethyl ester of *N*-ethyl-*o*-methylcarbanilic acid, was much more effective than either ingredient alone, and also more effective than M-250.

Nine of the mixtures in the second series of tests were definitely superior to M-250, with ratios varying from 1.31 to 4.15. Only one mixture was inferior and one was approximately equal to M-250. In the nine superior mixtures other ingredients were substituted for *Indalone*, whereas the other two contained 20 per cent of *Indalone*.

Six additional paired tests were run comparing M-2042 and OM-323, both of which combined *o*-chloro-*N*,*N*-diethylbenzamide with other repellents. No significant difference was apparent. The protection periods ranged from 271 to more than 499 minutes with M-2042 and from 272 to more than 528 minutes with OM-323.

Field tests against salt-marsh mosquitoes.—A series of tests with eight mixtures, including M-250 as the standard, was conducted against a mixed population of *Aëdes taeniorhynchus* and *A. sollicitans*. Exposures were continued until six bites on each arm were received. Each species contributed some of the earlier and some of the later bites, an indication that there was no difference in the effectiveness of the repellent against the two species. Protection time was calculated in two ways, on the time to the first confirmed bite and the average time to each of the six bites, to determine whether mixtures that were most effective on the basis of complete protection were also the most effective on the basis of partial protection. The results are presented in table 2.

The mixtures showed the same relative effectiveness by both methods of calculation, but differences between mixtures were smaller when the index was based on the average for 6 bites. M-2020 gave the highest ratio, and M-2016 the second highest, by both criteria, whereas M-1616 and M-1806 formed the lowest group. All the other mixtures were slightly more effective than M-250. In the mixtures that were better than M-250, some or all of the *Indalone* or dimethyl phthalate or both was replaced by dimethyl carbate, propyl *N*,*N*-diethylsuccinamate, or 2-ethyl-1,3-hexanediol. In the mixtures less effective than M-250, the 2-ethyl-1,3-hexanediol was replaced by dimethyl carbate or propyl *N*,*N*-diethylsuccinamate. These results show that 2-ethyl-1,3-hexanediol contributes considerably more to the effectiveness of repellent mixtures against salt-marsh mosquitoes than does either dimethyl phthalate or *Indalone*.

Table 2.—Relative effectiveness of seven repellent mixtures in paired tests against *Aëdes taeniorhynchus* and *A. sollicitans* Repellent M-250 used as standard. Three replications.

Experimental Repellent Number	Minutes to—				Ratio	
	First Bite		Average of 6 Bites			
	Experimental	Standard	Experimental	Standard	First Bite	6 Bites
M-526	171	148	190	179	1.16	1.06
M-1616	125	217	160	194	.58	.82
M-1806	102	165	116	163	.62	.71
M-2015	100	85	121	115	1.18	1.05
M-2016[1]	94	72	143	99	1.31	1.44
M-2019	195	164	211	170	1.19	1.24
M-2020	225	110	235	152	2.05	1.55

[1] Two replications.

On the basis of these tests, four mixtures were selected for additional testing against salt-marsh mosquitoes. They included M-526, M-2015, and M-2020, which were better than M-250 and contained dimethyl phthalate, and also M-1616 as tests were being conducted with it in other regions. No further tests were made with M-2016 or M-2019 as neither contained dimethyl phthalate and it was desired to retain this repellent in the formula because of its known superiority against *Anopheles quadrimaculatus* and chiggers; moreover, neither mixture showed any advantage over M-2020. Seven new mixtures were also tested, six containing *o*-chloro-*N*,*N*-diethylbenzamide and one (M-2043) similar to M-2020 but with propyl *N*,*N*-diethylsuccinamate in place of dimethyl carbate. The mixtures were tested against *Aëdes taeniorhynchus*. The results are summarized in table 3.

The mixtures M-2020, M-2042, M-2043, M-2047, and M-2048 were definitely better than M-250. Each of these mixtures

Table 3.—Relative effectiveness of 11 repellent mixtures in paired tests against *Aëdes taeniorhynchus*. Repellent M-250 used as standard. Three replications.

Experimental Repellent Number	Minutes to First Bite: Experimental Repellent	Minutes to First Bite: Standard Repellent	Ratio
M-526	172	158	1.09
M-1616	101	103	.98
M-2015	207	190	1.09
M-2020	187	81	2.31
M-2042	183	141	1.30
M-2043	213	132	1.61
M-2044	153	153	1.00
M-2045	172+	164	>1.05
M-2046	170	151	1.13
M-2047	270+	190	>1.42
M-2048	228	147	1.55

outlasted M-250 in all the individual tests, and showed ratios of 1.30 to 2.31. As in the preceding series, M-2020 showed the highest ratio, but not the longest protection time, as protection periods with the standard were unusually short. M-2015 outlasted M-250 in all individual tests, but by an average of only 17 minutes, giving a ratio of 1.09. The other five mixtures were sometimes more and sometimes less effective than M-250, with ratios ranging from 1.13 to 0.98.

Table 4.—Relative effectiveness of seven repellent mixtures in paired tests against *Aëdes taeniorhynchus*. Three tests with each mixture except as indicated.

Series	Paired Mixtures[1]	Minutes to First Bite
1	M-526	105
	M-2048	146
	M-2020	134
	M-2042	237+
	M-2046	99
	M-2047	108
2	M-2042	183
	M-2046	77
	M-2043	221
	M-2048	160
3	M-2043	86
	M-2047	151
	M-2042[2]	137
	M-2047[2]	126
4	M-2042[3]	367
	M2047[3]	374

[1] Tested as 25-per cent solutions in series 1 to 3, when protection periods were extremely long, and undiluted in series 4.
[2] 5 tests.
[3] 6 tests.

The best five mixtures and also M-526 and M-2046 were subjected to further testing against *Aëdes taeniorhynchus* by pairing each one against another, and eliminating the poorer. The results are presented in table 4.

In the first series of pairing, M-526 and M-2020 were eliminated by comparison with M-2048 and M-2042, respectively, whereas M-2046 and M-2047 were equal, and both were carried forward. In the next series M-2046 and M-2048 were eliminated by M-2042 and M-2043, respectively. In the third series M-2043 was eliminated by M-2047, but M-2042 and M-2047 were equal in three regular tests, and in two subsequent tests. These two mixtures were then compared at full strength, in two sets of three tests each, and were again equal in effectiveness.

Table 5.—Relative effectiveness of outstanding repellent mixtures in paired tests against *Aëdes sollicitans*. Three replications.

Paired Mixtures	Minutes to First Bite
M-250	101
M-2020	72
M-250	94
M-2042	156
M-250	60
M-2043	131
M-250	47
M-2047	139
M-2020	90
M-2042	92
M-2020	105
M-2043	110
M-2020	107
M-2047	102
M-2042	126
M-2043	94
M-2042	157
M-2047	131
M-2043	94
M-2047	137

M-2042 and M-2047 and the two mixtures (M-2020 and M-2043) that gave the highest ratios in the tests reported in table 3 were compared in a series of tests against *Aëdes sollicitans*. Each mixture was tested three times against each other mixture and against the standard, M-250. Protection periods were very short, even though mixtures were tested at full strength. The results in the individual pairings are presented in table 5.

M-2042 was superior to each of the

other mixtures except M-2020 in the direct comparisons and showed the highest over-all average for 12 tests. M-2047 was superior to M-250 and M-2043, and M-2043 was superior to M-250.

The results with M-2020 were inconsistent, as it was inferior to M-250 in the direct comparison, but equal to each of the other mixtures, all of which were superior to M-250. In the over-all average it was superior to M-250.

The average protection time for 12 tests with each mixture and the ratios in comparison with M-250 were as follows:

Mixture number	*Minutes to first bite*	*Ratio*
M-250	76	—
M-2020	94	1.24
M-2042	133	1.75
M-2043	107	1.41
M-2047	127	1.67

Laboratory tests against Anopheles quadrimaculatus.—One series of tests was made to compare the effectiveness of three mixtures containing *o*-chloro-*N*,*N*-diethylbenzamide against *A. quadrimaculatus*. M-2042, which was the most effective mixture against salt-marsh mosquitoes, was included. These mixtures were paired against M-250 and against each other.

All of the mixtures were relatively ineffective against this species. The time to the first confirmed bite ranged from 40 to 63 minutes in three tests with OM-321, from 28 to 39 minutes in six tests with OM-323, and from 29 to 61 minutes in three tests with M-2042. M-250 failed after 35 minutes in one test and was effective for at least an hour longer than the material with which it was paired in five other tests, after which exposures were terminated.

The other mixtures have not yet been tested against *A. quadrimaculatus*.

SUMMARY.—Of the thousands of chemicals that have been tested by various agencies as mosquito repellents, less than a score have proved highly effective and also safe for unrestricted application to the skin. Experience has shown that mixtures of several good repellents are effective against a wider range of species and on more individuals than any one repellent used alone. Studies during World War II culminated in the selection of a mixture (M-250), consisting of 6 parts of dimethyl phthalate, 2 parts of 2-ethyl-1,3-hexanediol, and 2 parts of *Indalone*, for general use by the armed forces. Experiments have been continued to find other mixtures or individual repellents, of a higher general effectiveness than M-250. As in previous observations, the best over-all results were obtained with mixtures. The most effective mixtures against several species of *Aëdes* were dimethyl phthalate 4 parts, 2-ethyl-1,3-hexanediol 3 parts, dimethyl carbate 3 parts (M-2020); dimethyl phthalate 4 parts, 2-ethyl-1,3-hexanediol 3 parts, propyl *N*,*N*-diethylsuccinamate 3 parts (M-2043); 2-ethyl-1,3-hexanediol 4 parts, propyl *N*,*N*-diethylsuccinamate 3 parts, *o*-chloro-*N*,*N*-diethylbenzamide 3 parts (M-2042); and 2-ethyl-1,3-hexanediol 5 parts, *o*-chloro-*N*,*N*-diethyl benzamide 5 parts (M-2048).

Several of the most effective mixtures against *Aëdes* mosquitoes proved relatively ineffective against *Anopheles quadrimaculatus*.

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Resistance of *Anopheles quadrimaculatus* to DDT in the Tennessee Valley

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Aside from the laboratory demonstration by Fay *et al.* (1949) there has been inconclusive evidence indicating the possibility of *Anopheles quadrimaculatus* Say developing resistance to DDT. It has been generally reasoned that residual house spraying and larvicidal spraying operations affect such a small fraction of the total anopheline population that the development of a strain resistant to DDT would appear quite unlikely.

The Tennessee Valley Authority has employed DDT larvicides and formulations for adults in its mosquito control program since 1945. These chemical control measures have always been considered supplementary—principal reliance being placed upon biological control methods. There is, however, a continuing need for efficient larvicidal measures to meet emergency conditions. For this reason, an extensive study of aircraft larvicidal operations has been carried on through the years. The apparent development of a strain of *Anopheles quadrimaculatus* resistant to DDT has been observed during the study of aircraft applications of DDT for the control of larvae of this species.

Aircraft Larvicidal Unit Calibration.—It is a routine procedure of the Tennessee Valley Authority malaria control operation to calibrate and check the DDT spray equipment on all aircraft units prior to the beginning of each mosquito breeding season. The principal features of this examination include checking the discharge rate, pressure, particle size of droplets produced, and a bioassay on an experimental range with a fixed height of flight for determining swath width and larvicidal efficiency. The methods of determining the recovery of DDT and the particle size of the spray have remained essentially the same since 1944 and have been described by Kruse' & Metcalf (1946) and Kruse' *et al.* (1949). A swath 150 to 300 feet in width is sampled at intervals of 20 feet for mass of DDT recovered and larval kill. The standard test employs 20 insectary-reared fourth instar larvae of *Anopheles quadrimaculatus*. An 8- to 9-inch waterproof paper plate serves as the test container. After the spray has been applied, the plates are covered and mortality readings taken at the end of 24 hours. Up to three replicates have been employed on the ends of the swaths where the dosage is light, and in recent years replicates have been employed throughout the entire swath. At least three controls are set up with each test run and all mortality data are corrected by the use of Abbott's formula. There have been occasions during the years when certain experiments have been conducted using glass petri dishes or one pint ice cream cartons. These have not been included in the review of calibration experience.

On figure 1 may be seen in summary the evidence obtained from airplane larvicidal tests which indicates the possible resistance of insectary-reared *Anopheles quadrimaculatus* to DDT. On the upper left-hand chart are plotted the micrograms of *p,p'*-DDT per larva necessary to give an average 50 per cent mortality in 24 hours over a period of years. On the upper right-hand chart have been plotted the data of Decker & Bruce (1951) on LD_{50}'s for DDT applied topically to field-collected strains of adult houseflies during 1945–1950. The similarity of the anopheline LD_{50} curve to that of the resistant housefly is quite striking. It appears that the LD_{50} for *A. quadrimaculatus* remained unchanged until 1950 and 1951 when approximately 10 and 25 times the 1949 amount were required to obtain 50 per cent mortality. In the case of houseflies in Illinois where the strains are considered to be 100 per cent resistant, it may be seen that a 50-fold increase in DDT was required from 1945 to 1950 to produce a mortality of 50 per cent.

Another analysis was made from the records of airplane larviciding experiments. Three hundred and twenty-one range stations in the years 1946, 1949, 1950, and 1951 gave 100 per cent larval kill. The DDT recovery at these stations

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was tabulated by years and the mean recovery determined. These data are plotted in the lower left-hand chart of figure 1 which shows that a striking increase in the mean dose necessary to produce a 100 per cent larval kill was required even in 1950.

A summary of the amounts of DDT required to give LD_{90} values through the years presents an even greater degree of apparent resistance. Recovery data for several years are given in table 1.

All methods of testing for statistical significance of the airplane test data agree that the differences observed between 1944 and 1951 are real and are not due to chance. A large number of repeated trials involving some 25,000 mosquitoes have gone into these bioassays. Consequently the observers have considerable confidence in the results. For example, the data show that the LD_{90} dose in 1944 is equal to the LD_{50} dose in 1951. If there were no differences in the mosquitoes, the expected kill would be 67.5 per cent from an average of 20 mosquitoes per trial. The standard deviation of the difference was determined to be 2.7, with P being equal to 0.0069. This means that the difference in kill during 1944 and 1951 would have deviated as much or more by chance only seven times out of 1000 trials.

One of us (C.W.K.) has personally followed the airplane bioassay work through the years and has previously reported the noticeable increase in LD_{90} from aerosol to spray applications (Kruse' *et al.* 1951). Airplane aerosol was replaced by nozzle spray application in 1948. The difference between the two types of applications could not be explained on the basis of number of droplets recovered, particle size, or the solvent used. It was not until the data were separated by seasons that development of a strain of mosquitoes resistant to DDT was suspected.

There remain many unanswered questions as to how the insectary-reared mosquitoes developed a resistance to DDT. It must first be acknowledged that the insectary population is not a pure laboratory strain. It has been necessary at various times to reinforce the brood stock with wild-caught mosquitoes. Many of the mosquitoes have come from a chemical control area of Wheeler Reservoir where contact with chlorinated hydrocarbon insecticides is quite possible. One of the most promising hypotheses to be tested is the effect of cotton spraying on the mosquito population in adjacent areas. The amounts of organic insecticides applied to cotton in Alabama during recent years have been plotted on the chart in the lower right-hand corner of figure 1. Before 1947 very little crop dusting was undertaken in North Alabama and the figures supplied by the Commissioner of the Alabama Department of Agriculture give the estimates of use in the state from 1947 through 1950. Practically all of the arsenical type materials have been replaced with newer chlorinated hydrocarbons such as toxaphene, BHC, aldrin, dieldrin, and DDT. Of special interest is the fact that the increased use of these materials parallels the increase in required dosage necessary to obtain control of *Anopheles quadrimaculatus* larvae. Field reports show that where crop spraying has been undertaken the mosquito populations have been greatly reduced. In a number of instances there are reports of damage to fish and other aquatic life in streams and parts of the reservoirs as the result of heavy crop spraying coupled with surface-water run-off from these fields. It may develop that boll weevil control rather than mosquito control is responsible for the increased resistance of local insects to DDT. This has been partially confirmed by Ludvik *et al.* (1951) who could show no significant differences in the susceptibility to DDT of *A. quadrimaculatus* larvae from routinely treated and untreated areas of Kentucky Reservoir.

LABORATORY STUDIES.—In view of the large number of laboratory studies conducted in the past years on the toxicity of DDT to *Anopheles quadrimaculatus* it would appear a simple matter to determine to what extent, if any, have strains of mosquitoes developed resistance to DDT. Kearns *et al.* (1945) show the 48-hour MLD[1] for the Wilson Dam insectary strain to be 0.1 ppm DDT for both emulsion and acetone suspensions in distilled water. Ludvik[2] shows a 48-hour MLD with the present Wilson Dam strain to be 0.5 ppm DDT as an alcohol-distilled water suspension or about five times the dosage of 1945. Generally, the accepted 48-hour MLD for *A. quadrimaculatus* in

[1] MLD as used throughout this report refers to the minimum lethal dose of Trapido (1951).
[2] Unpublished data.

the United States is reported to be 0.01 to 0.02 ppm of DDT as an acetone-water suspension.

In studying the various reports, one notes very little standard procedure as to the number of larvae, volume and surface area of test solution, and formulation of DDT employed. For the most part test conditions are not comparable. Having no reliable laboratory reference point for the insectary mosquitoes in 1945, the problem of demonstrating the extent of resistance to DDT becomes quite difficult. Nevertheless, attempts were made to obtain data which could be compared with that previously published. From this work several factors were found to affect the evaluation of DDT suspensions and emulsions. These included stability in various types of containers, the number of larvae used per replicate, the volume of test medium, and the surface area available to the larvae. A detailed report of this phase of the problem has been prepared by Kruse' *et al.* (1952). In addition, certain of these and other factors have been stressed as being of considerable importance by Trapido (1951). Therefore, it appeared that a more uniform response would be obtained if the DDT were made available to the larvae as a surface film. Experiments were inaugurated with solutions of DDT in kerosene incorporating *Trex*, a spreading agent, to assure that the small quantity of solution added to the water surface would spread completely. The dosage of DDT applied was measured by drops from a calibrated #23 hypodermic needle and syringe. In this manner larvae could be set out in all test containers and be treated uniformly in a short space of time by adding the required number of drops to each container. The kerosene mixture applied to the surfae at a rate equivalent to 1 gallon of kerosene per acre did not produce significant mortality in the controls.

Of first interest was to establish the stability of the DDT-kerosene film in the test container with time. Several paper plates lined with wax paper were filled with 200 ml. of water and 15 micrograms of *p,p'*-DDT were applied to each as a kerosene film. Each container had 50 square inches of water surface. Fifty early fourth stage insectary larvae were added to the dish on a schedule of hours following the application of the surface

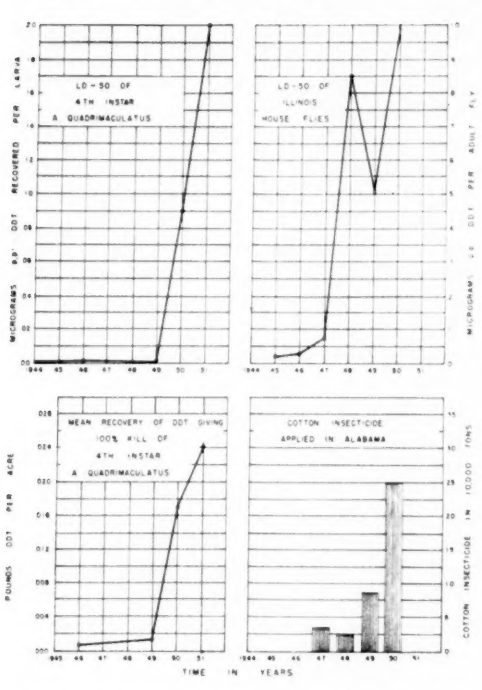
LD-50 OF 4TH INSTAR A. QUADRIMACULATUS
LD-50 OF ILLINOIS HOUSE FLIES
MEAN RECOVERY OF DDT GIVING 100% KILL OF 4TH INSTAR A. QUADRIMACULATUS
COTTON INSECTICIDE APPLIED IN ALABAMA
TIME IN YEARS

FIG. 1.—Amounts of DDT required for the control of *Anopheles quadrimaculatus* during the years 1944–1951.

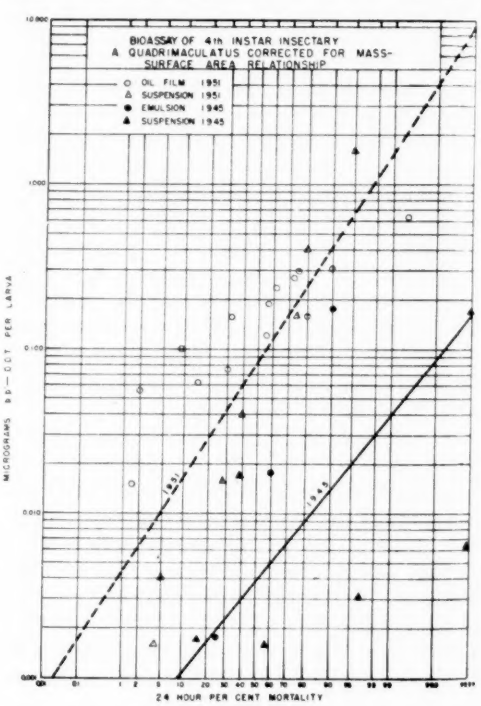
BIOASSAY OF 4th INSTAR INSECTARY A. QUADRIMACULATUS CORRECTED FOR MASS-SURFACE AREA RELATIONSHIP
OIL FILM 1951
SUSPENSION 1951
EMULSION 1945
SUSPENSION 1945
24 HOUR PER CENT MORTALITY

FIG. 2.—Comparison of *Anopheles quadrimaculatus* bioassay data for 1945 and 1951.

film. The mortality records were taken at the end of 24 hours. The results are given in table 2. These tests show that the DDT surface film will persist up to 17 hours at peak strength.

A large amount of toxicity data has been collected during the 1951 season using different containers, surface areas, volumes, and numbers of larvae for emulsions, suspensions, and oil films of DDT. Each formulation gives a different dosage-mortality curve which cannot be compared with the other. In an effort to find the common ground between these conditions and formulations, the data were reviewed with these several factors being kept in mind. A standard set of corrections has been made in order to approach the correct amount of DDT available per larva. The weakest assumption in the method occurs in the handling of the suspension and emulsion test data where it has been assumed that only the volume occurring in the first one-eighth of an inch below the surface is available to the larvae. All dosages are expressed in micrograms of *p,p'*-DDT per larva. The procedures used to correlate the various conditions and methods of testing are illustrated by the following equations:

a) Tests using oil films

$$\text{adjusted gamma per larva} = \frac{\text{gamma available per container}}{\text{number of larvae per container}};$$

where gamma available = gamma applied × effective area,

effective area $= 1\text{-}e^{-M}$,

M = number of larva per square inch of surface.

b) Tests using suspensions or emulsions

$$\text{adjusted gamma per larva} = \frac{\text{gamma available per container}}{\text{number of larvae per container}};$$

where gamma available = gamma per cubic inch × effective volume × effective area,

effective volume = area × $\frac{1}{8}$.

Adjusted values for the test data available for 1945 and 1951 are plotted against the observed mortality on figure 2.

It can be seen that the correction does not alter the slope of the dosage-mortality curve. The slope of the 1951 suspension curve on log probability paper is steeper than the oil film for 1951. The correction does, however, eliminate the wide scatter of the data from the two types of formulations. The 1945 data plotted as individual dosage-mortality curves do not collectively show good correlation with each other. It should also be noted that the numbers of larvae used for bioassay in 1945 were much smaller than the numbers used in 1951. The best line of fit for these data would tend to show a seventeen-fold increase in LD_{50} from 1945 to 1951 and a 23-fold increase in LD_{90}. Neither of these increases in dosage required to produce mortality is as spectacular as are the data from the airplane larviciding experience. Nevertheless, it appears safe to state that the laboratory bioassay confirms the suspicion of DDT resistance in the insectary-reared *Anopheles quadrimaculatus* at Wilson Dam.

Table 1.—Recovery required in Lbs. DDT/Acre for 90 per cent kill of insectary-reared 4th instar *Anopheles quadrimaculatus*.

Year	Lbs. DDT/Acre	Ratio to 1944
1944	.0005	1
1946	.0021	4
1949	.0019	3.8
1950	.0200	40.0
1951	.1300	260.0

AIRCRAFT LARVICIDAL FIELD TESTS.—During July and August 1951, a relatively stable pond in the vicinity of Hustburg, Tennessee, was found to be producing large numbers of *Anopheles quadrimaculatus* larvae in a rather wide marginal band of *Potamogeton*. This situation presented an excellent opportunity to check the effectiveness of our DDT larvicide. Fifteen sampling stations, each 20 feet apart, were located within the band of vegetation. The performance of the airplane spray application was checked by pre- and post-flight dipping and by droplet sampling on clean glass slides placed at each station just prior to the dawn spraying flight. The 10 pre-flight dips of one square foot each at each station were

Table 2.—Stability of DDT-kerosene-*trex* film with time.

Hours After Dosing	No. Larvae Used	Average Per cent Mortality
0	50	52.0
2	94	87.0
4	84	76.5
8	50	94.0
17	50	98.0
24	49	15.0
Control	100	2.0

made early the morning prior to the flight, while the post-flight dips were made the morning following the test flight. A total of three tests were completed, with two-week intervals being allowed between tests. For the first and third tests, an application rate of 0.05 lb. of DDT per acre was used, while the rate for the second was 0.1 lb. per acre. Eleven hundred and thirty larvae of all stages were obtained in the pre-flight dipping for the first test, while the post-flight dipping yielded 293 larvae. Only three stations across the 280-ft. range showed a mortality of 90 per cent or better. The preflight dipping for the third test (second at 0.05 lb. per acre) yielded 229 larvae with 45 being found at the end of the test. Here the results as far as the number of high mortality stations across the swath is concerned were considerably better than for the first test, with seven stations showing 90 to 100 per cent kill. These were not in a continuous 100-foot swath, however. The 0.1 lb. per acre application gave excellent results. One hundred per cent mortalities occurred at 13 of the stations with those at each end being 96 and 97 per cent. Seven hundred and seventy-five larvae were found prior to treatment, while only three larvae were found after treatment. It was felt that these tests definitely showed that the 0.1 lb. per acre application was required in the field to give the desired degree of control and that the 0.05 lb. per acre rate could no longer give the results experienced during the previous years of airplane spraying operations.

SUMMARY.—Comparisons of data obtained since 1944 from airplane spray tests with DDT have shown a 10- to 25-fold increase in the LD_{50} values for insectary-reared fourth instar *Anopheles quadrimaculatus* larvae occurred since 1949.

It has been shown that the mean amount of DDT required to give 100 per cent kill of fourth instar larvae has increased about 20 times during 1950 and 1951 as compared to the period 1946 through 1949.

Data from field tests carried out against a natural population have shown that it was necessary in 1951 to double the rate of application of DDT distributed by airplane in order to obtain results as satisprocedures utilizing differing volumes factory as during previous years.

Comparison of various laboratory tests of larvae exposed to DDT by several methods in 1945 and 1951 shows the occurrence of an increase in LD_{50} values in the order of 20 times.

An empirical method to correlate data obtained through various larval testing procedures utilizing differing volumes and surface areas of solution, numbers of larvae, and amounts of toxicant has been presented.

Acknowledgments.—The authors wish to thank all members of the Malaria Control Branch for their assistance in the various phases of the problems discussed. Special thanks are due Dr. T. F. Hall, former Chief of the Biology Section, for his unqualified support and encouragement during the course of this work.

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Responses of Apple Trees to Mite Infestations: I[1]

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While mites are generally believed to impair the productivity of apple trees through the feeding they do on the leaves, surprisingly little experimental evidence is available to support this belief. (See Groves 1951). Indirect effects of this nature are not readily measured.

Apple trees in common with other woody plants may maintain considerable food reserves in their tissues. This enables them to withstand periods of subnormal food production in the leaves—such as would be caused by mite feeding—without having this adverse condition be reflected, measurably, in the crop of the current season. Whether mite feeding may have delayed effects, as reducing the fruit setting rate or fruit bud formation the year following attack, does not appear to have been established, conclusively.

Two species of mites occur commonly in New York apple orchards, the European red mite, *Paratetranychus pilosus* (C. & F.), and the two-spotted spider mite, *Tetranychus bimaculatus* Harvey. Leaf injury caused by these species is often quite conspicuous. There is little evidence to show, however, that this feeding affects or has affected the productivity of our apple trees. Some growers, particularly in western New York, are now so little impressed with the injury-producing potential of mites that they have begun to question the necessity of carrying out control measures for them. Considering how much money and effort are expended annually to combat mites, it is obviously desirable that some attempt should be made to clarify their status as pests.

Such studies were initiated by the writers in 1951. An attempt is being made: (1) to determine whether or not mites are capable of causing economic damage to apple trees under western New York conditions, and (2) if so, what is the nature and extent of the injury. The present article is the first report on these investigations.

Experimental.—Two young orchards were selected for the experimental work projected. Some information on these two blocks is given in table 1. Although two varieties were present in the Nesbitt orchard and three in the Wilson Brothers block, these were interplanted in such a way that it was possible to include a similar number of trees of each variety in each experimental plot. All trees were in bearing and bore sizeable crops in 1950. Regarding the initial incidence of mites, winter eggs of the European red mite were present in numbers on all trees in the spring of 1951, and adults of the two-spotted spider mite were common on the various plants which comprised the ground cover under the trees.

Basically, the plan of the experiments carried out in these two orchards was very simple. Mites were kept under control in half of the trees and left unchecked in the remaining half.

The Nesbitt orchard used consists of nine and one half rows, 49 trees long, and the experimental block includes the four and one half western rows. The orchard lies on nearly level terrain, although the central portion is slightly depressed. The experimental block was divided into eight nearly square plots which contained 27 trees each on the average. The eight plots permitted four replications of the two variables tested. Treated and untreated plots were arranged in alternating sequence and in a single line.

All of the trees were used for experimentation in the Wilson Brothers orchard. It consists of 18 rows, 21 trees long. The terrain in this planting is somewhat rolling but not of such a nature as to affect tree growth and yields importantly. Any tendency in this direction is believed to have been amply compensated for by using large plots, 30 trees each on the average, and six replications. As in the Nesbitt block, treated and untreated plots were alternated throughout, but because the present block was nearly square, the plots were arranged in three tiers of four plots each.

The owners of each orchard applied a full series of spray treatments for the control of the insect pests and diseases that

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Table 1.—Information on the two experimental orchards.

Orchard Owner and Location	Year Trees Planted	Varieties and No. Trees of Each		Number Experimental Replicates
D. Nesbitt Albion, N. Y.	1939	Cortland	96	4
		Red Delicious	121	
		Total	217	
Wilson Bros. Waterport, N. Y.	1939	Rome	81	6
		Macoun	111	
		Red Delicious	172	
		Total	364	

are common to this area but were careful to omit all acaricides. Mite control treatments were applied as special sprays by Experiment Station personnel. Treatment was limited, of course, to those trees which we wished to keep virtually mite-free. Two acaricidal sprays were applied: at the end of the blossom period on May 24, and just two months later, July 24. Treatment formula was 1.5 pounds (1 pound in 7/24 spray) of 50 per cent P-chlorophenyl p-chlorobenzene-sulfonate,[3] and one-third pint of 20 per cent tetraethyl pyrophosphate in 100 gallons of water.

Leaf samples were taken on seven occasions during the season to determine the mite populations present. The record for the variety Cortland in the Nesbitt orchard is given in figure 1. Separate population records were taken in untreated trees for each variety and for each replicate of each variety. A composite single sample was taken for each variety from treated trees. A record of seasonal mite incidence for all varieties is given in table 2. These data are perhaps of special interest because of the wide variation shown in the maximum population level attained between varieties. Specimens of the two-spotted mite were found in all leaf samplings, but they constituted only a small percentage of the total population. The data given in table 2 and figure 1 include counts of both species but are essentially those for the European red mite. Failure of the two-spotted mite in untreated trees to become abundant in August in the manner reported by Lienk & Chapman (1950) is believed due to the severe feeding done earlier by the European red mite.

The trees comprising the two experimental blocks are probably more uniform in size and growth than those usually encountered in this area. Nevertheless, considerable size variation was found to exist as shown by trunk girth measurements. Not all of the variation found can be attributed to differences in soil, drainage, or similar effects, since a few trees were replants. These were 2 to 3 years younger than the original planting and, consequently, included all of the trees of smallest girth. The influence of tree size on yield is shown generally in the data given in tables 3, 4 and 5. This relationship is shown graphically for the Cortland trees in figure 2. A high correlation, namely +0.86, was found between yield

[3] Ovotran. Dow Chemical Company.

Table 2.—Mite populations present in treated and untreated trees of the two experimental orchards in 1951.

Orchard	Apple Variety	Average Number of Hatched Mites per Leaf on Sample Dates						
		5/24	6/11	6/25	7/11	7/23	8/8	8/20
		Mites controlled[1]						
Nesbitt	Cortland	6.0	0	0.3	2.8	3.6	1.2	1.4
Nesbitt	R. Delicious	4.7	0	0.6	4.9	10.6	0.6	0.6
Wilson	R. Delicious	—	0.3	0.2	0.9	1.9	1.0	0.3
Wilson	Macoun	—	0	0.1	0.6	0.8	0.2	0.2
Wilson	Rome	—	0	0.2	0.7	1.7	1.4	0.8
		Mites not controlled						
Nesbitt	Cortland	6	53	47	182	23	10	8
Nesbitt	R. Delicious	5	75	68	295	40	25	17
Wilson	R. Delicious	—	129	29	151	48	19	26
Wilson	Macoun	—	31	21	55	15	14	6
Wilson	Rome	—	46	16	105	37	26	8

[1] Acaricidal treatments applied 5/24 and 7/24.

Table 3.—Yield, fruit size and trunk girth increase in 1951 of Cortland apple trees where mites were controlled and not controlled. Nesbitt Orchard, Albion, N. Y.

Mite Status	Range in Initial Trunk Girth (Inches)	Number Trees Observed	Yield in No. Fruits			Ave. No. Picked Fruit per Bushel	Yield in Bushels			Trunk Girth Increase in 1951, Inches		
				Reduction				Reduction			Reduction	
			Ave.	No.	Per Cent		Bu.	Bu.	Per Cent	Ave.	In.	Per Cent
Controlled	8–13.9	9	409	—	—	115	3.5	—	—	1.96	—	—
Not controlled	8–13.9	11	451	+42	+10.3	120	3.5	0.0	0.0	1.60	0.36	18.4
Controlled	14–15.9	10	879	—	—	126	6.8	—	—	1.78	—	—
Not controlled	14–15.9	13	673	206	23.4	121	5.4	1.4	20.6	1.67	0.11	6.2
Controlled	16–17.9	17	1158	—	—	125	9.1	—	—	1.87	—	—
Not controlled	16–17.9	15	926	232	20.0	125	6.6	2.5	27.5	1.73	0.14	7.5
Controlled	18–21	11	1190	—	—	110	10.5	—	—	1.97	—	—
Not controlled	18–21	8	825	365	30.6	108	6.7	3.8	36.2	1.78	0.19	9.6
Controlled	Average	47	962	—	—	120	7.9	—	—	1.90	—	—
Not controlled	Average	47	740	222*	23.1	122	5.7	2.2*	27.8	1.69	0.21*	11.1

* Significant at 1% level.

and trunk girth for the mite-free trees; it was only +0.61 for the injured trees. Perhaps this difference in correlation between the two tree groups is in itself a reflection of mite injury.

As will be seen, growth and yield data (Tables 3, 4 and 5) are presented on the basis of tree size categories. Analyses of variance were made on the data based both on tree size groupings and on the plots as originally established, which latter treatment, of course, disregards tree size. Because the sub-sample numbers were unequal, the analysis of variance used is that given by Snedecor (1946). Very similar results were obtained in the analyses. That is to say, questions of whether or not data were significant, or to what degree, were not affected by tree grouping.

RESULTS.—The following records were taken on each of the 581 trees in the two blocks: measurements of trunk girth at the beginning and end of the growing season; an estimation of the amount of bloom produced; record of fruit yields on all varieties except Macoun, measured as total number of fruit and number of bushels produced, number of fruit per bushel, and number of dropped and picked fruit.

Samples of leaves were collected for chlorophyll, nitrogen, and mineral determinations. Also, fruit color data were obtained on representative numbers of Cortland fruits. Lots of both Cortland and Red Delicious fruits were pressure tested for firmness at harvest and on several later occasions. A series of branches on treated and untreated trees were marked and were observed for fruit setting, influence of leaf-fruit ratios on fruit size, quality, and so forth. It is hoped that the detailed records taken on leaves, flowers and fruit occurring on these marked branches will provide information on the

Table 4.—Yield, fruit size and trunk girth increase of Red Delicious apple trees bearing 5 bushels and more in 1951, where mites were controlled and not controlled. Nesbitt Orchard, Albion, N. Y.

Mite Status	Range in Initial Trunk Girth (Inches)	Number Trees Observed	Yield in No. Fruits			Ave. No. Picked Fruits per Bushel	Yield in Bushels			Trunk Girth Increase in 1951 (Inches)		
				Reduction				Reduction			Reduction	
			Ave.	No.	Per Cent		Ave.	Bu.	Per Cent	Ave.	In.	Per Cent
Controlled	14–16.9	7	1205	—	—	174	5.7	—	—	1.62	—	—
Not controlled	14–16.9	7	1103	102	8.5	162	6.6	0.1	1.5	1.58	0.04	2.5
Controlled	17–17.9	6	1581	—	—	183	8.3	—	—	1.85	—	—
Not controlled	17–17.9	7	1357	224	14.2	166	7.9	0.4	4.8	1.59	0.26	14.1
Controlled	18–21	10	1730	—	—	179	9.3	—	—	1.76	—	—
Not controlled	18–21	8	1592	138	8.0	187	8.4	0.9	9.7	1.60	0.16	9.1
Controlled	Average	23	1532	—	—	179	8.3	—	—	1.74	—	—
Not controlled	Average	22	1362	170	11.1	173	7.7	0.6	7.2	1.59	0.15*	8.6

* Significant at the 5% level.

Table 5.—Yield, fruit size and trunk girth increase in 1951 of Rome apple trees where mites were controlled and not controlled. Wilson Bros. Orchard, Waterport, N. Y.

Mite Status	Range in Initial Trunk Girth (Inches)	Number Trees Observed	Yield in No. Fruits			Ave. No. Picked Fruit per Bushel	Yield in Bushels			Trunk Girth Increase in 1951 (Inches)		
				Reduction				Reduction			Reduction	
			Ave.	No.	Per Cent		Ave.	Bu.	Per Cent	Ave.	In.	Per Cent
Controlled	12–15.9	14	783	—	—	128	6.0	—	—	0.99	—	—
Not controlled	12–15.9	13	609	174	22.2	126	5.2	0.8	13.3	0.95	0.04	4.0
Controlled	16–17.9	15	1118	—	—	102	8.6	—	—	1.06	—	—
Not controlled	16–17.9	18	948	170	15.1	123	7.9	0.7	8.1	1.07	+0.01	+0.9
Controlled	18–21	5	1071	—	—	119	10.5	—	—	1.20	—	—
Not controlled	18–21	7	1221	+149	+13.9	117	9.4	1.1	10.5	1.09	0.11	9.2
Controlled	Average	34	973	—	—	124	7.8	—	—	1.05	—	—
Not controlled	Average	38	883	90	9.2	119	7.2	0.6	7.7	1.03	0.02	1.9

effect of mites, if any, on fruit bud formation and fruit setting in 1952 and beyond.

TREE GROWTH.—The amount of vegetative growth made by test trees was determined by measuring the circumference of the trunk at a marked point before and at the end of the growing season. Such girth measurements provide a good overall index to growth. Data may be expressed directly as inches increase, or in terms of total area of increase. The former alternative was used here.

A record of the amount of growth made by trees where mites were controlled and not is given for three varieties in tables 3, 4, and 5. Greater growth was made by uninfested trees, being 1.9 per cent greater for Rome, 8.6 per cent greater for Red Delicious, and 11.1 per cent greater for Cortland. Only in the case of the Cortland trees were the differences significant.

FRUIT YIELDS.—Data on fruit yields are given for all of the Rome and Cortland trees, and for the Red Delicious trees in the Nesbitt orchard which produced five[4] or more bushels of fruit. Yields from the Red Delicious and Macoun trees of the Wilson Brothers orchard were considered to be too light and erratic for use. The yield records obtained on the other trees are presented in tables 3, 4 and 5.

Examination of these data will reveal that mite-controlled trees out-yielded mite-injured trees both in terms of bushels and in numbers of fruits produced. No appreciable differences in fruit size were found. (Information on size will be found in fruit-per-bushel data.) The most striking yield differences were found in the variety Cortland. Mite controlled trees of this variety produced 23.1 per cent more fruit per tree and 27.8 per cent more bushels of fruit. A plot of these data on an individual tree basis is given in figure 2. These yield differences for Cortland trees

Table 6.—Reduction in chlorophyll content of leaves resulting from mite infestations.

Orchard	Apple Variety	Kind of Leaf, and Date Sampled	Chlorophyll[1] Reduction (Per Cent)
Nesbitt	Cortland	Spur, July 19	31*
	Cortland	Shoot, Aug. 16	25*
	Cortland	Spur, Oct. 12	31*
	Red Delicious	Spur, July 19	33*
	Red Delicious	Shoot, Aug. 16	29*
	Red Delicious	Spur, Oct. 12	34*
Wilson	Macoun	Spur, July 19	28*
	Rome	Spur, July 19	14†

[1] Each record is based on eight or more single tree samples from each treatment. Chlorophyll is calculated on a leaf area basis and determined by the method of O. C. Compton and D. Boynton as reported in Proc. Amer. Soc. Hort. Sci. *46*: 45–50. 1945.
* Significant at 1% level.
† Significant at 5% level.

[4] Yields for this variety varied from a dozen fruits to 13.5 bushels per tree and were directly related to the amount of bloom originally produced. Desiring to include only those trees that bore a "normal" crop, a line was arbitrarily drawn at five bushels.

Table 7.—Amount of red color on Cortland fruits from treated and untreated trees, 1951.

Fruit Area Showing Red Color (Per Cent)	Per Cent Fruit in Each Color Class	
	Mites Controlled (4 trees)	Mites Not Controlled (4 trees)
0– 24[1]	12	6
25– 49	22	18
50– 74	38	40
75–100	28	36

[1] To meet U. S. No. 1 grade, Cortland fruit must have 25% or more red color.

were highly significant. The differences shown for Red Delicious and Rome were not significant.

The fact that more fruits reached maturity on the trees where mites were controlled is of special interest. Data taken on marked branches suggest that this condition is a result of a better fruit setting rate. These records show in Cortland 50 per cent setting for each 100 flower clusters on mite-free branches, as against only 41 per cent on injured branches. All Cortland trees produced a full amount of bloom, and conditions for pollination were excellent. The initial set of fruit was heavy. From the foregoing data and the record at harvest, table 3, it can only be inferred that mite injury to the leaves was the factor which controlled the final fruit setting rate between the two tree classes. The June drop of Cortland fruits in 1951 was relatively late and heavy on all trees regardless of their mite status.

CHLOROPHYLL.—Leaf disc samples were taken for chlorophyll analyses at three periods. Results of these analyses are given in table 6. As will be seen, mite feeding caused significant reductions in chlorophyll content. The October 12 record is of special interest. The writers, among others, have often witnessed what appeared to be at least a partial recovery of normal leaf functioning following a mite attack as evidenced by leaf color. The record here on chlorophyll indicates that in the present case there was little or no recovery.

FRUIT COLOR.—Many workers, as summarized by Groves (1951) and reported by Lathrop & Hilborn (1950) and Lathrop (1951), have observed that mite-injured trees produce fruit of interior color. Some color data were taken on representative sampels of picked Cortland fruit in the present experiment. Eight similar trees were selected for sampling, four mite-injured and four uninfested. These bore a total of 69.3 bushels or approximately 8.7 bushels per tree. An equal number of fruits was taken from each orchard crate to provide a two-bushel sample from each tree. The next day each fruit was carefully graded into one of four color classes, and the results obtained are given in table 7.

As will be seen, the uninfested trees produced less highly colored fruits on the average than did mite-injured trees. Most of the poorly colored fruit from all trees came from the centers of the trees where light conditions were lowest. And it is well known that sunlight has a profound effect on red color formation in apple fruits. Since the uninfested Cortland trees possessed leaves of deeper green color and denser over-all growth, less sunlight reached the centers of these trees, and this simple fact probably accounts for the results shown in table 7.

OTHER OBSERVATIONS.—No significant differences were found in the 1951 crop between infested and uninfested trees in respect to the following: in the ratio of dropped to picked fruit; in fruit firmness as determined by a Magness-Taylor pressure tester at harvest, after being held 10 days as $\pm 70°$ F. or after 180 days at 32° F.; and in the percentage of soluble solids present in the fruit.

DISCUSSION AND CONCLUSIONS.—Only tentative conclusions will be drawn on the

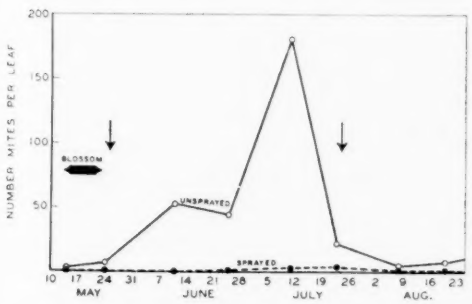

FIG. 1.—Seasonal record of mite abundance in treated and untreated Cortland trees. Arrows indicate when acaricidal treatments were applied. 1951.

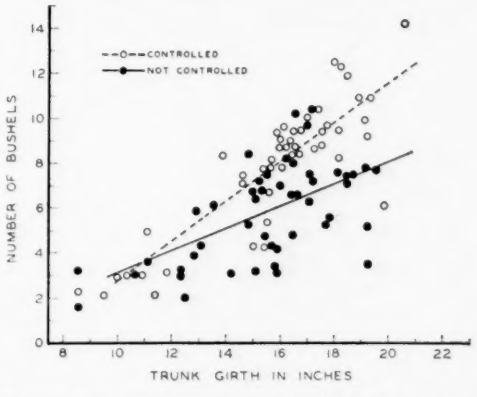

FIG. 2.—Correlations between yield in bushels and tree size (girth) in 48 Cortland trees where mites were controlled and in 48 trees where mites were not controlled. 1951.

data presented here since the findings encompass a period of only one growing season.

Although yield differences between mite injured and uninjured trees ranged up to 27.8 per cent for the Cortland variety, the writers were unaware that any differences surely existed until the crop was picked and yield records were analyzed. Apparently this is a normal experience. For, there are those who claim that with fruit crops *in situ*, one may not see yield differences ranging up to 25 per cent or even greater. If this assertion is correct, then it may well account for the general difficulty growers and others have had locally in determining whether or not economic injury is caused by mites to apple trees. Evidently, considerable damage may be done without this condition being evident from a general inspection or one unsupported by detailed yield records.

Earlier workers have often claimed that mite injured apple trees produce fruit of smaller size, poorer color, and drop earlier than do uninjured trees, Groves (1951) and Lathrop (1951). None of these effects were noted in the present experiments. However, the writers realize that under certain conditions injured trees might well respond in one or more of these ways.

Using the Cortland data as an example since differences here were the most pronounced, no significant difference in fruit size (Table 3) was found between treated and untreated trees. Apparently any tendency to produce larger apples on these treated trees was completely offset by the setting of more fruit. Mite injury would be expected to reduce fruit size, especially if appreciable early leaf drop occurred. Essentially, no mite-induced leaf drop took place in the present tests.

Whether or not fruit color is adversely affected by mite activity is probably determined by tree vigor, growth-density, variety of apple and other conditions prevailing in the individual orchard. In the case of the Cortland trees the fruit color differences noted were similar to those one would expect to find between groups of trees maintained at high and low nitrogen levels. More highly colored fruit will be produced on the less vigorous trees in such situations, that is, on those kept on a short nitrogen program. In the present case, leaf analyses do show a lower nitrogen content in mite injured leaves than those from uninfested trees. (It is planned to develop this subject and other more strictly pomological aspects of the problem in a later paper.) All of the Cortland trees would have benefited from pruning prior to the start of growth in 1951 for they were rather dense for young trees. The foliage became decidedly yellowish and dull on mite injured Cortland trees. In the mite-free trees the leaves were dark green and the over-all growth was denser.

It is planned to continue the studies reported here into 1952 and possibly beyond. The same experimental blocks will be used, and the identical plot layouts of 1951 maintained.

SUMMARY.—Half of the trees in two young apple orchards were kept virtually free of mites in 1951 through the use of two acaricidal treatments, while in the remaining trees these pests were allowed to develop unchecked. These conditions were maintained to measure what effect, if any, mites may have on the productivity of apple trees under local conditions. This paper reports the results obtained the first year of the investigation.

Heavy populations of the European red mite, *Paratetranychus pilosus* (C. & F.), developed in untreated trees, but the two-spotted spider mite, *Tetranychus bimaculatus* Harvey, was unimportant in the two orchards in 1951 in spite of the fact that this species occurred both in the trees and on the ground cover.

Among the varieties of apples that produced normal crops in 1951, larger yields were realized from the trees where mites were controlled. Such trees produced not only more bushels of fruit but more fruits per tree. These yield differences were not statistically significant except for the Cortland variety. Mite-free Cortland trees out-yielded infested trees 27.8 per cent on the average and produced 23.1 per cent more fruit. Mite infestations apparently had no effect on fruit size in these experiments in 1951. Trunk girth measurements made before and at the end of the growing season showed that uninfested trees made more over-all growth, being 11.1 per cent greater in the Cortland variety.

Contrary to the reports of earlier workers, better color occurred on fruit from mite-injured trees, at least in the variety Cortland. Over-all growth was

less dense in infested trees of this variety, and this condition apparently permitted better penetration of sunlight to the less exposed fruits.

Mite feeding reduced the chlorophyll content of the leaves from 15 to 35 per cent, depending on the variety and intensity of mite infestation. No apparent effect was caused by the mites on fruit firmness at harvest or after several months storage, or on the total soluble solids content of the fruit.

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Tests on Pea Aphid Control in Alfalfa and Residues from Various Formulations at Harvest

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A heavy infestation of pea aphid, *Macrosiphum pisi* Kalt., in alfalfa during the summer of 1950 in Oswego county, New York offered a good opportunity to investigate the efficiency of various methods of applications, as well as to test various insecticides for its control. These experiments consisted of applications of insecticides with a low pressure, low gallonage sprayer using emulsions; a thermol aerosol using oil and water fogs; and a fertilizer spreader using impregnated and regular ribbon mill mixed dusts. While the sprays and aerosols were only used once, the dusts were applied in a schedule based on several stages of plant height. Such a control schedule also presented an opportunity to study the best time to apply treatments of insecticides in order to obtain good aphid control with a minimum of residue on the hay at harvest time. Hence investigations were also made of the residues on the hay.

The insecticides used in these tests, as emulsions, were aerosol grade DDT, technical grade DDT, benzene hexachloride, dieldrin and toxaphene; aerosol grade and technical grade DDT in oil and water mists; and impregnated aerosol grade DDT, impregnated technical grade DDT and regular ribbon-mill mixed DDT in the dust treatments.

LOW PRESSURE, LOW VOLUME SPRAYER TESTS.—A low pressure, low volume sprayer mounted on a tractor was used in these tests. The sprayer had a 20 foot boom, mounted 33 inches above the ground, equipped with 13 fan type[2] nozzles. Thirty pounds pressure was developed from a gear type power take-off pump which delivered 15 gallons per acre at a calibration using the slowest tractor speed. Benzene hexachloride, dieldrin, toxaphene, aerosol grade of DDT and technical grade DDT were applied June 7, 1950 to a field of alfalfa-timothy mixture at rates of 0.1, 0.2, and 0.3 pounds of actual toxicant per acre. The alfalfa was approximately 22 inches high at the time of the application. Pea aphid counts were taken at regular intervals for one week, these counts were made from 20 net sweeps per treatment taken in several locations chosen at random. The results of these counts for the various intervals are recorded in table 1.

Samples for residue analysis were taken in all of the plots at the time of application and at harvest by taking 3 one-square foot samples of standing hay in several random locations in each treatment. Each sample was stripped with an appropriate solvent and all the residues which are expressed in parts per million were determined on a green weight basis. DDT was determined by the colorimetric method as described by Schecter *et al.* (1945), while

[1] The authors wish to acknowledge the financial support given these investigations by the Geigy Co., Inc. of New York.

[2] Teejet No. 650067, Spraying Systems.

Table 1.—A summary of the control of the pea aphid with the low-pressure, low volume sprayer using five materials at three concentrations and the residue in ppm. (green weight) at the time of application and at harvest. Oswego County, New York. 1950.

Toxicant	Actual Amt./A.	Per Cent Control in: 24 Hrs.	96 Hrs.	1 Wk.	Residue (ppm)[1] Application	Harvest
Aerosol	0.1	68.3	85.4	94.7	2.5	1.2
Grade	0.2	90.5	89.6	91.8	3.0	1.3
DDT	0.3	74.0	87.4	97.1	3.1	1.7
Technical	0.1	57.9	88.2	88.4	.09	.01
Grade	0.2	65.4	92.4	93.7	2.9	1.0
DDT	0.3	89.9	95.9	94.7	6.1	2.1
	0.1	51.6	83.9	85.0	0.4	.66
BHC	0.2	50.0	95.2	85.5	2.7	.30
	0.3	77.9	94.5	92.1	7.3	2.8
	0.1	52.3	68.6	77.2	—	—
Dieldrin	0.2	76.7	78.4	73.9	—	—
	0.3	64.4	87.5	72.9	—	—
	0.1	48.5	25.9	34.5	0.9	0.1
Toxaphene	0.2	35.6	23.9	20.1	0.6	0.0
	0.3	43.7	23.4	33.1	0.8	0.5

[1] Acknowledgment is made of the work of Dr. L. B. Norton and his assistants in analyzing all of the residue samples.

benzene hexachloride was determined by the method of Tufts *et al.* (1950). Analysis of toxaphene was made by the total organic chloride method. The results from the chemical analysis of these samples are recorded in table 1.

In conjunction with the above tests, a similar experiment was set up on June 12, 1950 in a pure stand of alfalfa which was 33 inches in height at the time of application. As this field was to be cut later than the previously described one, insect counts, taken in a manner as indicated previously, were continued for a longer period. The materials used in this experiment were emulsions of aerosol grade DDT and technical grade DDT which were applied at 0.5, 1.0 and 2.0 pounds of actual toxicant per acre. The control results from these tests are recorded in table 2.

Samples of alfalfa for analysis of the residue at application and at harvest were taken in a manner as previously described. The residues on a green weight basis are reported in table 2.

These experiments indicate that the low pressure, low volume sprayer is a very effective machine for pea aphid control. Good distribution of small amounts of insecticides can be obtained. As little as one-third of a pound of DDT per acre gave excellent control at the end of one week. See table 1. Benzene hexachloride, at the same concentration in these tests, was

Table 2.—A summary of the control of the pea aphid and residue of DDT at the time of application and at harvest, using two formulations of DDT at three concentrations as emulsions. Oswego County, New York. June, 1950.

Toxicant	Actual Amt./A.	Per Cent Control in: 48 Hrs.	1 Wk.	2 Wks.	2 Wks.	Residue (ppm)[1] Application	Harvest
Aerosol	0.5	70.4	86.1	59.7	00.0	37.6	9.0
Grade	1.0	92.9	94.2	79.2	37.0	47.3	8.6
DDT	2.0	96.0	100.0	97.0	75.0	110.7	19.9
Technical	0.5	69.4	94.2	91.1	25.0	9.9	3.3
Grade	1.0	90.9	93.1	95.6	12.5	32.8	6.6
DDT	2.0	89.8	96.6	89.6	54.2	52.4	17.1

[1] Residue calculated from green weight.

also very effective but in other trials it proved to be erratic. Dieldrin and toxaphene gave poor kills of the aphids at the low concentration used and cannot be suggested for use at these rates per acre. The higher kills obtained with the smaller 0.2 and 0.3 pounds per acre dosages of DDT in the first experiment over the larger 0.5 pounds per acre dosage in the second experiment is believed to be due to better coverage as the tests were applied to smaller, upright plants. When the half pound dosage was applied in experiment 2, the alfalfa was 11 inches taller in height and heavily lodged and as a result poorer coverage and control was obtained at that time. Best results with the low pressure, low gallonage sprayer are obtained when the insecticide is applied early when good coverage can be obtained. Early applications also tend to reduce the insecticide residue at the time of harvest since there is a greater period for weathering and growth.

Residues from even small amounts of emulsion insecticides were found to persist much longer and were very much greater in actual amount at harvest than residues from very much larger amounts of the same insecticide applied as dusts. The residues from the emulsions are apparently not as easily subjected to wind, sun, and rain erosions as are the residue of other formulations.

Thermal Aerosol Tests.—A commercial type thermal aerosol applicator[3] mounted on a truck was used in these tests, employing 3 per cent oil solutions and water emulsions of aerosol grade and technical grade DDT at a temperature at the nozzle of 1050° F., with a gas pressure

[3] "TIFA" Todd Shipyard Corp.

Table 3.—A summary of the control of pea aphids obtained with the thermal aerosol applicator using two formulations of DDT and, the residue at varying distances from the nozzle at harvest. Oswego county, New York. 1950.

Toxicant	Formulation	Distance from Machine	Per Cent Control in:		Residue in ppm at Harvest
			48 Hr.	2 Wks.	
Aerosol Grade DDT	Water Emulsion	10	100.0	100.0	23.9
		25	85.8	93.9	00.0
		50	85.8	24.7	00.0
	Oil Solutiln	10	100.0	98.8	66.9
		25	98.0	98.8	13.1
		50	77.6	61.8	4.2
Te hnical Grade DDT	Water Emulsion	10	98.0	98.8	226.0
		25	98.0	82.8	3.7
		50	67.4	35.9	00.0
	Oil Solution	10	98.0	100.0	18.6
		25	89.8	90.2	3.5
		50	8.17	48.2	00.0

of 40 pounds and a particle size setting of the machine (as indicated by the gauge) of 12 microns. To avoid any air movement which might interfere with coverage, the treatments were applied in the early morning of August 16, 1950. The alfalfa was 10 to 15 inches in height at the time of application. Aphid counts were made in a manner as previously described at the intervals indicated in the table. A summary of the results of these counts are recorded in table 3.

Residue samples were also taken in this experiment in a manner as previously described except that samples of hay were taken only at harvest. These samples were taken at 10, 25 and 50 feet from the nozzle in order to determine the differences in deposit of residue at these distances. All the plots were harvested and sampled on August 30, 1950. These data are recorded in table 3.

During the experiment there was very little precipitation. The dry spell combined with the hot weather prevented any new growth of alfalfa. It is believed that the lack of new succulent growth, that would be favorable to new pea aphid infestations, may account for the good control figures obtained even after 2 weeks. These data show a camparable control of aphids with the oil solutions and with the water emulsions at distances up to 25 feet; however, the oil solutions carried farther than the water emulsions and gave a higher kill at distances beyond 25 feet from the nozzle of the applicator.

The residue samples taken at the 3 distances from the nozzle were quite variable between similar samples indicating an uneven coverage, but there was a high correlation between control of the aphids and the average deposit at the 3 distances from the nozzle. At distances beyond 25 feet, there was little to no residue at harvest indicating that swaths of no more than 25 feet should be used where a prolonged control of the aphid is desired. No generalization can be made as to the difference in persistency of residues between water emulsions and oil solutions because there was no consistency of residue deposits with either of the 2 types of materials. However, some of these inconsistencies may be in part due to the unevenness of deposit between samples.

The aerosol method of insecticide application does not seem to be nearly as applicable for aphid control in alfalfa as some of the other methods with other more common types of machinery since it was found in other experiments to be too dependent on weather conditions. Since only a strip 25 feet wide is the maximum area that can be adequately covered, it is believed that a low pressure, low gallonage sprayer could do the job as quickly and as well. In fact, under adverse wind conditions the sprayer would probably be superior to the aerosol machine.

DUSTS AND TIMING BY PLANT HEIGHT TESTS.—A hand fertilizer spreader was used in these tests in order to obtain an even distribution of the insecticide in small plots. One per cent impregnated aerosol grade and impregnated technical grade DDT dusts were used at a rate of 200 pounds per acre. In an adjacent area a test was made using 5 per cent ribbon-mill mixed DDT dust at a rate of 1000 pounds per acre. These dusts were applied at four stages of growth of the alfalfa starting July 25, 1950: on the stubble, at 2 inches of growth, at 4 inches of growth and at 6–8 inches of growth. The treatments were made at 6 to 7 day intervals, depending on the amount of growth of the plants. See table 4. Aphid counts were made from net sweepings taken at 48 hours and at weekly intervals for three weeks. The results of these counts are recorded in table 4.

Hay samples for analysis of residues were taken in a manner previously described, at the time of the dust application and 3 weeks later. These residues are recorded in table 4.

Table 4.—A summary of the control of the pea aphid and the insecticide residues at harvest obtained with 2 formulations of DDT when applied[1] with a hand fertilizer spreader at different stages of growth of alfalfa. Oswego county, New York. 1950.

Toxicant	Plant Height	Per Cent Control in:				Residue (p.p.m.)	
		48 Hrs.	1 Wk.	2 Wks.	3 Wks.	Applic.	Harvest
Aerosol grade DDT	Stubble	100.0	97.8	79.3	00.0	0.6	00.0
	2″	79.9	85.1	50.2	27.3	59.3	00.0
	4″	100.0	97.0	85.6	24.6	94.1	0.4
	6–8″	97.8	91.5	74.4	48.0	25.6	0.6
Technical grade DDT	Stubble	100.0	97.8	57.5	2.2	0.5	00.0
	2″	100.0	94.3	60.7	24.6	42.4	00.0
	4″	100.0	96.3	74.7	17.6	60.1	0.3
	6–8″	100.0	93.7	85.2	31.0	22.7	00.0

[1] Dates of application: on stubble July 25; on 2 inches, August 1; on 4 inches, August 7; and 6–8 inches on August 14, 1950.

These data show little difference in effectiveness of technical grade and aerosol grade DDT; both grades, at the dosages used, gave very good control of the pea aphid for more than one week regardless of when applied.

It is interesting to note that at the time of application the 4 inch stage of alfalfa consistently retained more residue than shorter or taller alfalfa. This unusual phenomenon may in part be explained by the growth habit of alfalfa. After alfalfa is cut, it requires about 4 to 6 days in New York for the stubble to start "leafing out." At this stage, the new leaves grow laterally until the ground between the pants is well covered. At the 2-inch stage, the ground is only partly covered, therefore, any application of insecticide is largely lost on the bare ground. By the 4-inch stage, the lateral growth is largely complete and much of the application of insecticide is caught and retained by the alfalfa mat. At the 6 to 8 inch stage, the alfalfa begins to grow rapidly upward with lengthening internodes and branches so that when the applicator passes over this growth, it is pushed or blown over, allowing the insecticide to filter through the plant unto the ground.

Recorded in table 5 are the aphid control results and residues from applications of 1000 pounds of a 5 per cent DDT dust per acre.

The large amount of DDT did not control aphids any better or keep them under control longer than much smaller amounts. After the third week the control is directly proportional to the time of application. The plots treated at the latest stage of growth showed a larger percentage of control at the end of 3 weeks than the ones treated earlier.

The control obtained with the impregnated dusts applied at the rate of 2 pounds per acre of actual DDT was no better than the results obtained with 0.3 pound per acre of actual DDT applied as an emulsion.

Even when as much as 50 pounds per acre of DDT was applied, the residue was rapidly lost under New York conditions. Three weeks later, or at harvest, the residue was no greater than when 0.5 pound per acre of DDT was applied as an emulsion. Regardless of the initial amounts of insecticide applied, the residues were rapidly lost in amounts directly proportional to the amounts applied, so that 3 to 4 weeks after application the actual amount of residue that can be found on the plants from any size dosage is about the same.

Summary.—A heavy infestation of pea aphids in alfalfa in Oswego county, New York offered an opportunity to test various insecticides for pea aphid control as well as to study residues and various

Table 5.—A summary of the results obtained with heavy applications of DDT as a dust (50 pounds per acre) applied at different growth periods. Oswego (Oswego County), New York. 1950.

	Plant Height and Per Cent Control			
	Stubble	2 Inches	4 Inches	6–8 Inches
48 hrs.	100.0	100.0	100.0	100.0
1 wk.	93.4	95.4	100.0	91.6
2 wks.	46.1	76.5	82.5	83.1
3 wks.	100.0	64.3	35.8	36.9
Residue (ppm)				
Application	16.3	443.5	365.5	226.2
Harvest (3 wks.)	1.9	5.9	8.2	3.2

methods of insecticide application. Benzene hexachloride, toxaphene, dieldrin, aerosol grade DDT and technical grade DDT as well as regular ribbon mill mixed DDT dust were applied.

These preliminary tests indicate that 0.3 pound per acre of aerosol or technical grade of DDT applied with the low pressure sprayer offers the best means of control for pea aphids in alfalfa, providing the alfalfa is not over 24 inches in height at the time of treatment. Impregnated aerosol grade and impreganted technical grade DDT dusts at 2 pounds per acre of actual toxicant also gave good control when applied to the alfalfa 6 to 8 inches in height. Applications at 3 stages of growth did not show any increase or decrease in the period of control, all giving about 10 days of effective control.

The thermol aerosol applicator gave good control for a limited distance from the nozzle. Oil solutions and water emulsions of aerosol grade and technical grade DDT gave comparable results in these tests.

Heavy applications of 5 per cent DDT (50 pounds per acre of actual toxicant) applied on the stubble and at 2 inches of growth only gave approximately the same degree of control and remained effective for only a time comparable to impregnated DDT dusts at 2 pounds per acre of actual toxicant. This heavy dosage was slightly inferior to the low pressure spray applications of 0.3 pound per acre of toxicant. These data indicate that it is not wise to over-dose or to expect a heavy concentration of DDT, applied 2 to 3 weeks after the first cutting of alfalfa to offer control of pea aphids for an extended period of time.

Aerosol grade and technical grade DDT were superior to the other insecticides tested for pea aphid control. There was little to choose betweeen the two grades of DDT on a performance basis alone but technical grade is the more economical to buy.

Either grade of DDT applied as an emulsion with a low pressure, low gallonage sprayer gave the best control with the least amount of material as compared to higher dosages and other methods of application.

Hay samples for residue analysis were taken at the time of each application and at harvest in each experiment. Residues from the application of emulsions with a low pressure, low gallonge sprayer were found to be much more persistent than residues from other formulations and other methods of application. Residue analysis of applications made with a thermol aerosol machine indicate that its effective control swath is about 25 feet from the nozzle. The thermol aerosol residues of water emulsions and oil solutions appear to be equally persistent on alfalfa.

Residue analysis from dust applications applied at four stages of growth on alfalfa showed that a larger deposit was found on the four inch stage, consistently. This phenomena is thought to be due to the growth habit of alfalfa.

As much as 50 pounds per acre of DDT as a dust applied to alfalfa had residues at harvest that were approximately equal to the residues were only 2 pounds per acre of DDT are applied as a dust. Regardless of the initial amounts of insecticide applied, the residues are rapidly lost in amounts directly proportionate to the amounts applied, the final residues being about equal in size.

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Tagging Oriental Fruit Flies with Radioactive Phosphorus for Field-Movement Studies[1]

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The marking of insects for field-movement studies has presented a serious problem with respect to techniques that can be readily adapted to large numbers of insects. One solution of this problem has been the use of various radioisotopes to tag insects for identification at various time intervals after their release. The methods employed by Hassett and Jenkins (1949), Yates *et al.* (1951), and Lindquist *et al.* (1951) to produce radioactive mosquitoes, house flies, and blow flies were investigated to determine which of their techniques would be most suitable for the production of radioactive oriental fruit flies, *Dacus dorsalis* Hendel.

In the first experiment potassium dihydrogen phosphate containing radioactive phosphorus (P^{32}) was added to the carrot medium used for routine production of oriental fruit fly larvae at the rate of 0.1 microcurie of P^{32} per milliliter. Two hundred milliliters of this radioactive medium were placed in a small plastic dish. Approximately 500 *Dacus dorsalis* eggs were then placed on the surface of the medium and the ensuing larvae were reared to maturity in this medium in approximately 6 days. The only changes from routine procedures were those dictated by the hazards due to the radioactivity. In a second experiment the amount of P^{32} was increased to 0.34 microcurie per milliliter. In both experiments samples of third-instar larvae, pupae, and adults were removed and assayed for radioactivity. All counts were taken with a shielded end-window Geiger-Mueller tube with a thickness of less than 2 milligrams per square centimeter and a background of 20 ± 2 cpm (counts per minute). Owing to the high counting rates figures are given to the nearest 100. The counts were taken on intact insects which could not be placed in exactly the same positions with reference to the counting tube. This and variations in size undoubtedly affected the counting rates for individual flies to some extent.

Although the larval-feeding method resulted in flies with a high degree of radioactivity, the data in table 1 indicate that there are serious limitations in the use of this method of tagging flies when the objective is to distinguish between flies released simultaneously at several points. The difference in radioactivity from the two markedly different amounts of P^{32} used in the carrot medium and consumed by the larvae was not adequate to distinguish between all individuals in the two lots of flies. The flies were sufficiently radioactive, however, to permit their identification in releases made at time intervals of the half-life of P^{32}, or 14.3 days, by

Table 1.—Radioactivity (counts per minute) of various life stages of oriental fruit flies reared in a carrot medium containing 0.1 and 0.34 microcuries of radioactive phosphorus per milliliter.

0.1 μc/ml.			0.34 μc/ml.		
Third-instar Larvae	Pupae	Adults	Third-instar Larvae	Pupae	Adults
3800	4800	1900	5300	4800	3200
4600	5200	2900	5100	5100	3500
3400	5200	2100	5800	5600	2600
4100	4100	2800	5300	5400	3700
4400	4500	2200	5600	5000	3800
4200	4200	2900	4700	4500	3000
4100	3800	2400	5800	5200	3300
3700	3400	2400	4900	4700	3500
4100	3100	2500	5300	5400	3000
4700	5300	2600	5300	5000	3400

[1] The radioactive phosphorus and instruments for assay of radioactive materials were provided by the Chemistry Department of the Pineapple Research Institute in Honolulu, T. H.

Table 2.—Radioactivity (counts per minute) of adult oriental fruit flies after feeding for 24 and 48 hours on a sugar solution containing 3.9 microcuries of radioactive phosphorus per milliliter.

After 24 Hours		After 48 Hours	
Females	Males	Females	Males
2800	2400	4200	5600
2300	2800	4900	3900
5000	3400	5700	4000
3600	3500	6300	4800
3300	3300	3700	5000
1920	3800	5400	4900
4500	—	3800	4300
2200	—	—	—

taking advantage of radioactivity decay and excretion losses.

The next experiment was made to determine the uniformity of amounts of P^{32} acquired through adult feeding. After 24 hours without food or water, 600 three-day-old oriental fruit flies were allowed to feed for 48 hours on a sugar solution containing 3.9 microcuries of P^{32} per milliliter. The normal diet of the flies was then restored. Samples of flies were assayed after 24 and 48 hours of feeding on the P^{32} solution.

The data for these tests, which are presented in table 2, show that the adult-feeding method likewise has limited usefulness in the identification of flies in simultaneous releases at several points. The differences in radioactivity of the two lots of flies were not adequate for the positive identification of all flies according to the period of feeding on the P^{32} solution. The lack of uniformity in the flies also suggested that this method would be of questionable value for studies requiring the positive identification of flies released at different time intervals.

To evaluate a method for separating the tagged flies in field-trap catches, three groups of oriental fruit flies, each containing radioactive flies, were stored in a lure solution containing 8 per cent of raw sugar, 1.3 per cent of vinegar, and 4 per cent of yeast per liter of water, at room temperatures in order to simulate field-collection conditions. At the end of one week the flies were filtered from the lure solution and arranged in a row on a piece of paper folded lengthwise. The flies were then pulled underneath an end-window Geiger-Mueller tube connected to a survey meter equipped with a loud speaker for aural monitoring of the simulated trap catch. The flies were approximately 0.25 inch from the end of the tube. A burst of sound from the loud speaker indicated flies containing P^{32}. Such flies were moved to one side and later examined individually with the counter to confirm their marking. Counts were made for 1 minute with a shielded Geiger-Mueller tube attached to a scaler to distinguish between adult flies marked at different times with different amounts of P^{32}.

The results of these experiments show that it is possible to detect flies tagged by either the larval- or adult-feeding method up to 40 days after emergence or feeding on P^{32}.

The amounts of P^{32} acquired by larvae or adults vary considerably, as shown in tables 1 and 2. It was therefore desirable to determine the rate of loss, by excretion or oviposition, of P^{32} acquired by the different methods of tagging. From 10 to 15 flies were removed at various time intervals and the amount of P^{32} present was determined by counts on intact individuals. Figure 1 indicates that the rate of loss of P^{32} differs with the method of tagging and suggests that differences in the biochemical distribution and rate of turnover of the P^{32} may be involved.

When the samples of flies were separated according to sex, it soon became apparent that the females reared from lar-

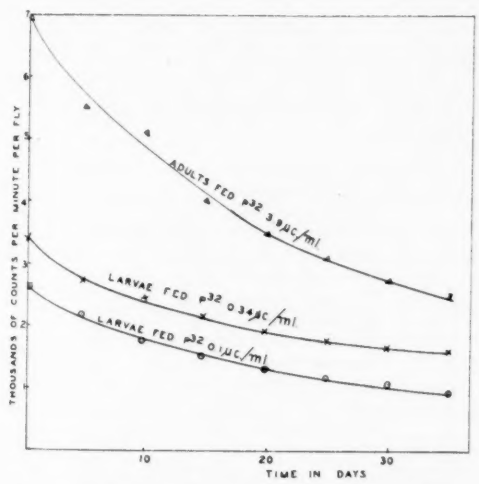

FIG. 1.—Rate of loss, by excretion and/or oviposition, of P^{32} acquired from larval or adult feeding. Data represent the averages of both sexes. Initial point represents first day of emergence or cessation of adult feeding on P^{32}.

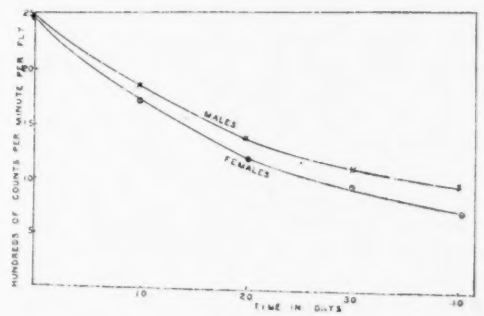

FIG. 2.—Rate of loss of P^{32} by adult males and females reared from larvae feeding on a medium containing 0.1 μc. of P^{32} per milliliter.

vae feeding on a radioactive medium were losing P^{32} at a more rapid rate than the males. These differences are illustrated in figure 2. An 80-mg. sample of eggs collected from these flies 15 days after their emergence gave a reading of 1000 cpm. While this amount of radioactivity is inconsequential from the standpoint of producing radioactive progeny, it is important as a factor contributing to the loss of P^{32} by the parent female.

Neither the flies produced from larvae feeding on a medium containing P^{32} nor adults feeding on a sugar solution containing P^{32} showed any adverse effects from exposure to the different levels of radiation. Flies produced from larvae feeding on a radioactive medium were subjected to a longer exposure to the beta activity of P^{32}. These flies were equal to the normal laboratory strain in percentage emergence from pupae, in fecundity, in fertility, in viability of larval progeny, and in longevity under laboratory conditions.

The use of P^{32} did not complicate normal rearing procedures unduly, since laboratory personnel came in contact with the materials only while mixing the radioactive acid potassium phosphate with the larval medium and at the time the larvae were removed for pupation. The use of rubber gloves and quantitative techniques minimized operator exposure and prevented laboratory or personal contamination.

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Toxicity of Insecticides to Some Predaceous Insects on Cotton[1]

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Since the development of the recent organics, there has been increasing interest in their effect upon the beneficial insects. DeBach (1951) blamed DDT for the increase in scale insects, mites, and mealybugs on citrus. In 1945, Loftin noticed an increase in *Aphis gossypii* and *Tetranychus* sp. following the use of DDT. Recently, Newson and Smith (1949) suggested that chlorinated materials were affecting the natural balance that exists between the cotton aphid, spider mite, and the bollworm and their natural enemies. Remedial measures to solve the insecticide vs. beneficial insect problem have not been overlooked. Ripper *et al.* (1951) believed the problem could be solved by the use of selective insecticides; whereas DeBach (1951) thought the problem should be approached from an ecological view, and Ullyett (1948) suggested a rational combination of insecticidal treatment and biological control as the most satisfactory method of combating insect pests.

In the summer of 1951, tests were conducted at the Delta Branch Experiment Station, Stoneville, Mississippi to determine which insecticides had the least effect upon the beneficial insects found on cotton. During the investigation the following predators were found to be present:

Order—Coleoptera
Family—Coccinellidae
Adalia bipunctata (L.)
Ceratomegilla fuscilabris (Muls.)
Coccinella 9-notata (Hbst)
Cycloneda munda (Say)
Hippodamia convergens (Guerin)
Olla abdominalis (Say)
Olla abdominalis plagiata (Casey)
Scymnus sp.
Order—Hemiptera
Family—Anthocoridae
Orius insidiosus (Say)

PAID PAPER.

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[3] The writer wishes to acknowledge the valuable advice rendered by Mr. S. L. Calhoun and Dr. E. W. Dunnam.

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Family—Lygaeidae
Geocoris punctipes (Say)
Family—Nabidae
Nabis ferus (L.)
Family—Reduviidae
Order—Neuroptera
Family—Chrysopidae
Chrysopa sp.
Order—Orthoptera
Family—Mantidae

Frequent observations were made in the field to determine the food sought by the various species. The coccinellids were consistently observed feeding upon aphids and spider mites. On one occasion a coccinellid larva was seen eating into the dorsal portion of *Heliothis* sp. larva and the spotted ladybeetle, *C. fuscilabris*, was observed attacking a mass of eggs belonging to the yellow striped armyworm, *Prodenia ornithogalli* Guen. The big eyed bug, *G. punctipes*, was more often observed with a mirid nymph impaled on its beak; whereas *N. ferus* seemed to prefer leafhoppers. On two occasions adult and nymphal *Geocoris* failed to pierce eggs of the bollworm moth while in confinement in the insectary. The eggs were probably those of the moth *Heliothis armigera* (Hbn.) but *H. virescens* (F.) was also present in the cotton field.

Upon reviewing the literature concerning the food and feeding records of predaceous insects, it was found that *O. insidiosus* was considered the most important enemy of the spider mite, *Septanychus* sp. (Iglinsky & Rainwater 1950). During the period from 1924 to 1927, Barber (1936) gave *Orius* credit for destroying 38.47 per cent of the eggs of the bollworm moth and Fletcher & Thomas (1943) credited this species with destroying 52.3 per cent of the larvae. In 1943, Ewing and Ivy list this species as an important enemy of the cotton aphid. As for the enemies of the spider mites, McGregor & McDonough (1917) found that *G. punctipes* consumed an average of 83 mites per day and *O. insidiosus* an average of 32.56 per day. This is not intended to be a complete list of the food of these predators, but rather an attempt to illustrate their importance in the cotton field and the necessity for maintaining these individuals at high population levels.

EXPERIMENTAL METHODS AND EQUIPMENT.—Laboratory tests were conducted on several of the more abundant predators using the insecticides indicated in the tables. The experiments were started in June and continued through August. Cotton cuttings which were to be sprayed or dusted were carefully selected so that each contained two leaves and approximately the same leaf area. The cuttings were kept fresh during the four day test period by placing them in vials containing a stock nutrient solution. These vials were buried in dirt and sand filled flower pots. Gauze covered lantern globes served as cages in all laboratory tests. Equipment for treating the plants consisted of a dusting tower and a rotary or turntable sprayer. A pressure necessary to disperse the dust was supplied by a plunger of the doorstop variety. Dusts were previously weighed so that a greater number of plants could be treated in a relatively short time. The sprayer was calibrated to put out the desired amount of toxicant in one revolution over the plant. All test insects were collected in the field with a sweep net prior to each experiment. The insects were not subjected to direct treatment; therefore the effect of the insecticides was proportional to the insects' activity on the treated surface. Mortalities were calculated according to Abbott's formula. Ten individuals were used per replicate in the case of *C. fuscilabris* and *H. convergens*. Five individuals were used per replicate in the other tests. Tests involving *H. convergens*, *Scymnus* sp., and *G. punctipes* were replicated six times, *C. fuscilabris* nine times, and the dust treatments of *N. ferus* were replicated three times and the sprays six times.

Three field plots, which were primarily set up for cotton pests, were utilized for studying the effects of field applied insecticides on predaceous populations. Each plot (dieldrin, DDT, and toxaphene) was 40 rows wide and approximately 200 yards long. The area of the untreated check approximated that of the treated. All insecticides were applied as sprays with a tractor equipped with a four row spray rig. The treatments consisted of nine applications as follows: May 25 and 28, June 5 and 25, July 9, 17, and 23, and August 2 and 7. On August 2 and 7, dieldrin was increased from 0.15 lb. toxicant per acre to 0.3 lb., DDT was increased from 0.5 lb. to 1 lb. and toxaphene was increased from 2.5 lbs. to 3 lbs. One hundred net strokes were made in

each plot with a 16-inch sweep net for population counts. Counts were taken before treatment and 24 and 48 hours after treatment.

RESULTS.—Since the various treatments affected the predators differently, each test will be discussed separately. In table 1 the data indicates that most insecticides are detrimental to the gray damsel bug, *N. ferus*. At the end of 96 hours the only insecticides which did not

Table 1.—Summary of results of laboratory tests to determine the effects of various insecticidal formulations on two hemipterous predators.

Treatment	Pounds Toxicant per Acre	Average Per Cent Mortality in Hours			
		48		96	
		Sprays	Dusts	Sprays	Dusts
Gray Damsel Bug, *Nabis ferus*					
Compound 269[1]	0.1	75	83	100	100
Compound 711[2]	0.2	57	—	67	—
Compound 923	2.0	88	—	100	—
DDT	0.5	100	0	100	25
Big-eyed Bug, *Geocoris punctipes*					
Compound 923	2.0	24	—	50	—
DDT	0.5	75	51	100	100

[1] A stereoisomer of dieldrin.
[2] A stereoisomer of aldrin.

completely eliminate this predator were Compound 711 when applied as a spray and DDT when applied as a dust. The big-eyed bug, *G. punctipes*, was virtually eliminated by all treatments except Compound 923 which caused an average mortality of 50 per cent at the end of 96 hours. Aldrin, chlordane, dieldrin, EPN, gamma benzene hexachloride, heptachlor, parathion and toxaphene were omitted in table 1 since they all

Table 2.—Summary of results of laboratory tests to determine the effect of various insecticidal formulations on the spotted ladybeetle, *Ceratomegilla fuscilabris*.

Treatment	Pounds Toxicant per Acre	Average Per Cent Mortality in Hours			
		48		96	
		Sprays	Dusts	Sprays	Dusts
Aldrin	.25	28	13	33	20
Chlordane	1	23	16	64	33
Compound 269	.1	63	45	70	77
Compound 711	.2	22	—	30	—
Compound 923	2	28	—	54	—
DDT	.5	52	18	76	39
Dieldrin	.15	19	12	54	40
EPN	.2	100	100	100	100
Gamma BHC	.4	69	82	87	89
Heptachlor	.35	17	14	34	36
Parathion	.1	100	100	100	100
Toxaphene	2.5	57	64	78	85
Calcium Arsenate	10	—	51	—	73

Table 3.—Summary of results of laboratory tests to determine the effect of various insecticidal formulations on the convergent ladybeetle, *Hippodamia convergens*.

Treatment	Pounds Toxicant per Acre	Average Per Cent Mortality in Hours			
		48		96	
		Sprays	Dusts	Sprays	Dusts
Aldrin	0.25	11	0	31	2
Chlordane	1.0	—	0	—	7
Compound 269	0.1	3	14	5	38
Compound 711	0.2	17	—	7	—
Compound 923	2.0	7	—	9	—
DDT	0.5	0	12	8	0
Dieldrin	0.15	14	0	23	8
EPN	0.2	90	73	100	90
Gamma BHC	0.4	33	11	48	26
Heptachlor	0.35	10	0	25	6
Parathion	0.1	100	100	100	100
Toxaphene	2.5	34	40	52	61

caused 100 per cent mortality to both species within 48 to 72 hours. The rate of application for insecticides omitted in this table may be found in table 2. The results shown in table 2 are more gratifying than those in the previous table. Although Compound 269, gamma BHC, toxaphene and calcium arsenate caused mortalities in excess of 70 per cent, only EPN and parathion completely eliminated the spotted ladybeetle, *C. fuscilabris*, Aldrin, Compound 711 and heptachlor caused lower mortalities than the other compounds used. Table 3 clearly shows that the convergent ladybeetle, *H. convergens*, is relatively tolerant to many of the insecticides. From this data it would be difficult to single out any one insecticide as having the least effect on this predator since aldrin, chlordane, Compound 269, Compound 711, Compound 923, DDT, dieldrin, and heptachlor caused less than 10 per cent mortality

Table 4.—Summary of results of laboratory tests to determine the effect of various spray formulations on the ladybeetle, *Scymnus* sp.

Treatment	Pounds Toxicant per Acre	Average Per Cent Mortality in Hours	
		48	96
Aldrin	0.25	31	44
Chlordane	1.0	55	17
Compound 269	0.1	41	70
Compound 711	0.2	16	5
Compound 923	2.0	78	100
DDT	0.5	45	84
Dieldrin	0.15	27	51
Gamma BHC	0.4	96	92
Heptachlor	0.35	43	54
Toxaphene	2.5	72	84

Table 5.—The effects of three field-applied insecticides on the predaceous insect populations found on cotton. The insecticides were applied as sprays June 25 and July 9. The figures in the table represent the number of individuals collected per hundred net strokes for each of the two applications.

	Treatment							
	Check		Dieldrin .15 lb. P/A		DDT .5 lb. P/A		Toxaphene 2.5 lb. P/A	
Predators	Before Treat.	48 Hr. After	Before Treat.	48 Hr. After	Before Treat.	48 Hr. After	Before Treat.	48 Hr. After
Hippodamia convergens	30	20	59	29	81	15	33	13
Ceratomegilla fuscilabris	61	14	51	15	41	3	14	4
Coccinella 9-notata	1	0	0	0	3	0	1	0
Scymnus sp.	3	0	3	0	0	3	1	1
Coccinellidae larvae	3	3	9	8	1	3	5	2
Chrysopa sp.	4	0	6	0	4	0	5	0
Nabis ferus	11	7	10	5	23	1	5	1
Geocoris punctipes	5	3	2	0	2	0	2	1
Orius insidiosus	17	4	13	2	9	1	10	3
Total Insects	135	51	153	59	164	26	76	25
Total per cent reduction under check				−1		22		5

when applied as either a spray or a dust. The data shown in table 4 involving the small coccinellid, *Scymnus* sp. indicates that chlordane and Compound 711 had the least effect; whereas aldrin, dieldrin and heptachlor were intermediate in their effect. It is probable that the percentage listed for chlordane is too low since there was an unusually steep drop between the 48 and 96 hour count. Although EPN and parathion were not used, it is reasonable to believe that they along with Compound 923 would have eliminated this small ladybeetle.

In general it may be said that all insecticides affected the predators; however, no conclusions can be drawn as to the dusts having a greater or less effect than the sprays. DDT was the only insecticide that consistently caused lower mortalities when used as a dust. As for the effects of specific insecticides on the predators, Compound 711 caused a lower mortality than any other insecticide used. Since the coccinellids comprised approximately 70 per cent of the predator population at Stoneville, the data given in the tables concerning these insects may be used as a means of dividing the insecticides into two groups; insecticides that have a moderate effect and the more potent insecticides. The first group would probably consist of aldrin, chlordane, Compound 711, Compound 923, dieldrin and heptachlor.

Results of the field tests, which are

Table 6.—The effects of three field-applied insecticides on the predaceous insect populations found on cotton. Insecticides were applied as sprays on August 2 and 7. The figures in the table represent the number of individuals collected per hundred net strokes for each of the two applications.

	Check		Dieldrin 0.3 lb. P/A		DDT 1 lb. P/A		Toxaphene 3.0 lb. P/A	
Predators	Before Treat.	48 Hr. After	Before Treat.	48 Hr. After	Before Treat.	48 Hr. After	Before Treat.	48 Hr. After
Hippodamia convergens	10	12	3	6	1	0	0	1
Ceratomegilla fuscilabris	34	43	35	32	10	1	24	10
Scymnus sp.	21	32	12	17	10	3	6	3
Coccinellidae larvae	46	38	31	8	6	3	8	5
Nabis ferus	35	22	12	0	12	0	11	0
Geocoris punctipes	3	3	2	0	0	0	0	0
Orius insidiosus	20	8	0	0	1	2	0	0
Total Insects	169	158	95	63	40	9	49	19
Total per cent reduction under check				28		71		55

Table 7.—Fluctuations in predatory populations and the relative abundance of the species.

PREDATORS	INDIVIDUALS COLLECTED PER HUNDRED NET STROKES ON UNTREATED COTTON ON THE DAYS INDICATED							
	June 25 & 26	July 9 & 10	July 19	July 24 & 25	August 2 & 3	August 7 & 8	August 17	Av. No.
Hippodamia convergens	39	11	7	4	11	4	4	6.7
Ceratomegilla fuscilabris	87	6	2	4	32	49	21	16.8
Coccinella 9-notata	3	0	0	0	0	0	0	0.3
Scymnus sp.	3	1	1	4	18	33	9	5.8
Cycloneda munda	0	0	0	0	0	1	2	0.3
Coccinellidae larvae	14	15	11	54	39	28	15	14.7
Chrysopa sp.	3	2	1	0	0	0	2	0.7
Nabis ferus	22	1	0	5	21	43	3	7.9
Geocoris punctipes	5	7	1	0	4	4	0	1.8
Orius insidiosus	11	15	8	4	16	16	1	5.9
Reduviidae sp.	0	0	0	0	1	1	0	0.1
Total Insects	187	58	31	75	141	179	57	60.7

shown in tables 5 and 6, indicate that dieldrin at both rates of application caused a lower reduction in total predators than either DDT or toxaphene. As in the laboratory tests, the Hemipterous insects were more seriously affected than the coccinellids. Although DDT caused higher reductions than toxaphene, it is interesting to note that the number of predators were never as great in the toxaphene plot. In the laboratory tests there was no difference in the effects of these two insecticides when applied as sprays.

The data in table 7 indicates that the coccinellids were the most abundant predators and the spotted ladybeetle was the most abundant species. The coccinellid larvae were predominately those of the spotted ladybeetle. The figures listed for *Chrysopa* sp. are probably too low since they take to flight with the least disturbance. As the data indicates there was an ebb in the predator population in mid July. This was not only true in this field but in other fields removed from this test. The peak of the predator population appeared to occur in early June with a secondary peak occurring the early part of August. During the period when the predators were scarce on cotton, it was found that they were very numerous and breeding heavily on corn. Coccinellids, *Orius* and *Chrysopa* were especially abundant but all species found on cotton were also found to be present on corn. This build up on corn may explain why the number of predators decreased as the distance from an adjacent corn field increased. This observation was made while collecting insects for toxicity tests. This might suggest the possibility of increasing the predators on cotton by planting a crop harboring similar host food adjacent to cotton. The application of insecticides during this mid summer ebb in predators, the time element of which would be increased by the natural lag in predators in relation to their host, coupled with the use of some of the less potent insecticides may suggest a means of alleviating the wide scale destruction of predators and allow them to add their controlling effect.

SUMMARY.—During the summer of 1951, laboratory and field tests were conducted to determine which insecticides had the least effect on the beneficial insects found on cotton. All insecticides used reduced the predators; however, Compound 711 at the rate of 0.2 lb. toxicant per acre caused a lower mortality than any other insecticide. EPN and parathion consistently eliminated the predators within the four day test period. In the field tests dieldrin applied at the rates of 0.15 lb. toxicant per acre and 0.3 lb. toxicant per acre caused a lower reduction in predators than either DDT or toxaphene. The Hemipterous insects in both the laboratory and field tests were more seriously affected than the coccinellids. *H. convergens* exhibited more tolerance to insecticides than any other test insect but unfortunately this species was not abundant after June.

Information based on sweeping records and observations indicated that the peak in predaceous populations occurred in June and the lowest ebb in mid July. Dur-

ing this ebb the predators were very abundant on corn. This apparent buildup on corn may explain why the predators were more numerous on cotton adjacent to corn as well as suggest the possibility of increasing the predators on cotton.

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Control of Sheep-ticks on Feeder Lambs[1]

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The sheep-tick, *Melophagus ovinus* (L.) is the most abundant and most widely distributed external parasite of sheep. Since the life history and control studies by Swingle (1913, 1915) much has been written concerning this insect. These papers have varied from short articles on biology to rather detailed control bulletins. Despite this extensive work, much remains to be done. A neglected field of study concerns the damage caused by the parasite. The objectives of the experiments reported here were (a) to study the influence of ticks on efficiency of feed utilized and on the gains made by lambs in the feed lot, (b) to appraise several methods of tick control, and (c) to compare efficiency of several chemicals. In addition to accumulation of data on these objectives, some information was obtained on the value of a sampling technique in determining populations of ticks on lambs.

METHODS AND PROCEDURES.—All experiments and studies were conducted on feeder lambs at the University of Nebraska, Scotts Bluff Field Station, Mitchell, Nebraska. Feeder lambs were purchased from Wyoming ranches. Experimental lots were confined in adequate pens, each of which was provided with watering and feeding facilities. Pens were separated by 2-foot alleys that were treated periodically with sulfur, DDT or benzene hexachloride to prevent sheep-tick migration.

The Experiment conducted during 1947–48 comprised six pens of 45 lambs each. The initial mean weight of the lambs was 70 pounds. The experiment was begun on November 25, 1947 and concluded on March 8, 1948. Each lot was fed a standard ration of grain mixture, containing equal parts of corn, barley, molasses, dry beet pulp and alfalfa hay. Treatments were applied by pen-spraying which involved crowding the lambs in a small pen and thoroughly spraying the backs, sides and as much of the underline as possible. A penetrating spray was delivered at 250 to 300 pounds pressure through a number 5 disc aperture.[2] The following treatments were used: (a) 4 pounds of 50 per cent wettable DDT in 100 gallons of water; (b) 6 ounces of cube powder (5 per cent rotenone) in 100 gallons of water, (c) 10 pounds of wettable

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[2] Five-sixty-fourths inch.

sulfur (325) mesh in 100 gallons of water, (d) 4 pounds of DDT plus 10 pounds of wettable sulfur in 100 gallons of water, (e) 6 ounces of cube powder (5 per cent rotenone) plus 10 pounds of wettable sulfur in 100 gallons of water, and (f) an untreated control. Tick counts were made prior to treatment, 30 days after treatment and at the end of the experiment. Counts consisted of the total number of ticks and viable pupae found in 10 evenly spaced 12-inch partings of the wool on each side of the lamb. The parts were distributed from the head to the tail. Ten randomly selected lambs were examined by this method in each pen at each counting.

In the 1948–49 experiment six pens of 24 lambs each were used; animals in each pen had an initial mean weight of approximately 90 pounds. The ration consisted of a corn and alfalfa hay mixture. This experiment was begun on November 13, 1948 and concluded on January 26, 1949. Treatments consisted of: (a) 4 pounds of 50 per cent wettable DDT in 100 gallons of water, (b) 10 pounds of wettable sulfur (325 mesh) in 100 gallons of water, (c) DDT-sulfur combination at the same dilutions, and (d) an untreated control. One lot was hand-dipped in the DDT-sulfur combination using a 300 gallon stock watering tank. Another was ribbon-sprayed with the DDT-sulfur combination as described by Shull *et al.* (1945). The remaining treated lots were pen-sprayed as in 1947–48. Tick counts were made in the same manner as in 1947–1948.

The 1950–51 experiment was conducted with 180 lambs confined in lots of 30 in each of six pens; the animals having an initial mean weight of approximately 55 pounds. The ration consisted of a grain mixture of corn, dry beet pulp, culled beans, cottonseed meal, alfalfa hay and dehydrated alfalfa pellets. The experiment was begun on October 16, 1950 and concluded March 24, 1951. Treatments consisted of: (a) 4 pounds of 50 per cent wettable DDT and 10 pounds of wettable sulfur (325) mesh in 100 gallons of water, (b) 6 ounces of cube (5 per cent rotenone) in 100 gallons of water, (c) 5.0 per cent cube (5 per cent rotenone) in wettable sulfur, and (d) an untreated control. The DDT-sulfur combination was applied in three ways, sheep in one pen were hand-dipped, those in another were pen-sprayed and the third group was ribbon-sprayed. Rotenone was applied by the ribbon-spray method to sheep in one pen and in combination with sulfur as a dust in another. The dustings were made with a power duster similar to that described by Denning & Pfadt (1950).[3] Tick counts were handled as in the previous years.

TICK SAMPLING TECHNIQUE.—Although much as been written concerning insecticides and methods for the control of sheep-ticks, little effort has been made to develop a scientific evaluation of such controls. Most workers have stated or implied the use of total population counts in comparing control measures. Total population counts, if accurately made, are preferable to any sampling method. The accuracy of such counts must, however, be questioned, particularly on very dense or loose wooled sheep. To the writers' knowledge only one worker, Dr. H. C. Manis, Moscow, Idaho, (oral communication), has attempted to sample sheep-tick populations. His method, which has not been published, involves examination of 10 well distributed sampling spots on each animal.

The possibility of accurately sampling a sheep-tick population was first indicated in a study by McLeod (1948). This study showed that the parasite favored the sides, upper legs, throat and brisket as resting or feeding areas. With this knowledge in mind, the sampling method described above was adopted.

During the first series of experiments there was considerable variation in the counts. Since these extreme population variations from sheep to sheep were not expected doubt arose concerning the validity of the counts. In order to validate or discredit the counts the following check was made. At the end of the lamb feeding period and just after the last tick count three of the sheep used for estimating the tick populations were selected at random from each pen. These animals, 18 in all, were closely sheared. The ticks remaining on each animal were carefully counted and supplemented with those found in the sheared wool. A statistical analysis of these total population counts and the final sample counts for the sheared sheep gave a highly significant correlation coefficient of 0.8878. The mean ratio of sampled to total ticks was approximately 1 to 10. Thus it appears

[3]Mimeographed, Wyoming Agr. Expt. Station.

Table 1.—Sample sheep-tick populations on feeder lambs before and after treatment with DDT, rotenone and sulfur. Scottsbluff, Nebraska, 1947–1951.

Mean Number of Sheep-Ticks per Sample[1]

Method of Application and Treatment	1947–48			1948–49			1950–51		
	Before Treatment	After Treatment, Days		Before Treatment	After Treatment, Days		Before Treatment	After Treatment, Days	
		30	102		30	71		30	156
Pen-Sprayed									
DDT—2 lbs./100 gals. H_2O	6.7	5.6	11.0	8.5	5.8	10.7	—	—	—
Sulfur—10 lbs./100 gals. H_2O	5.6	5.6	8.3	8.8	10.3	15.6	—	—	—
DDT—2 lbs.+Sulfur—10 lbs. 100 gals. H_2O	6.0	3.5	3.9	4.8	9.2	10.5	1.2	2.2	2.1
Rotenone—6 oz. cube/100 gals. H_2O	7.2	6.7	8.3						
Rotenone—6 oz. cube, Sulfur—10 lbs. 100 gals. H_2O	7.1	4.8	8.8						
Ribbon-Sprayed									
DDT—2 lbs.+Sulfur—10 lbs. 100 gals. H_2O	—	—	—	8.1	2.1	5.6	1.6	0.8	3.3
Rotenone—6 oz. cube—100 gals. H_2O							1.0	0.5	5.6
Dipped									
DDT—2 lbs.+Sulfur—10 lbs. 100 gals. H_2O	—	—	—	10.2	0.4	0.3	3.2	1.0	0.0
Dusted									
Rotenone—5.0 per cent cube in sulfur							3.0	1.6	1.0
Not Treated	7.2	12.7	12.4	5.5	6.0	10.7	3.2	11.0	4.2

[1] Each sample consisted of 20 wool partings (10 on each side) on 10 randomly selected lambs.

that a count of the ticks exposed in ten 12-inch wool partings on each side of a lamb is a valid sample of the actual population on that lamb and that this method may be confidently used in experimental studies such as are reported here. It should be realized, however, that the observed ratio of sampled ticks to actual populations probably varies according to season and geographical locality.

COMPARISON OF METHODS OF APPLICATION.—Since the early research of Swingle (1915) on the efficiency of dipping for the control of sheep-ticks several other methods have been devised for applying insecticides. Moore (1916) reported control of ticks by a fumigation with nitrobenzene. Shull *et al.* (1945) reported control of the parasite on unshorn sheep by spraying the head, neck and mid-line of the back with 400 pounds of pressure. This method is referred to as ribbon-spraying in the present paper. Matthysse (1945) developed a chute method of power dusting sheep for parasite control. Schwardt & Matthysse (1948), Denning (1949) and Denning & Pfadt (1950) modified and utilized this dusting technique in later control studies. About the same time Duncan (1945) reported on the pen method of spraying sheep which was also used by Shanahan (1946). French (1946) described a spray-chute similar to the dust-chute of Matthysse. This was a rather complicated piece of equipment but Shull *et al.* (1946) simplified it. No comparative evaluations of these new methods have been reported in the literature.

In the 1948–49 and 1950–51 experiments reported here an attempt was made to evaluate several methods of insecticide application. These were dipping, pen-spraying, ribbon-spraying and dusting. DDT-sulfur combinations were applied by the first three methods and rotenone-sulfur by the latter two. Results of these comparisons are shown in tables 1 and 2. Of the liquid methods of application, dipping was far superior to either pen or ribbon-spraying. Eradication or near eradication of ticks was obtained with dipping. Ribbon-spraying gave consistent reduction of tick populations which was maintained for 30 days but not after 60 to 90 days. Pen-spraying was inconsistent in effectiveness. In some cases population reductions were obtained whereas increases were noted in others. Rotenone-sulfur dusting was evaluated only in the 1950–51 tests. It appeared superior to a rotenone ribbon-spraying. Schwardt & Matthysse (1948) indicated the comparative effectiveness of dipping and dusting when they stated, that a rotenone dip ". . . will keep a flock largely tick-free for a year." Whereas rotenone dusting ". . . gave good commercial control of ticks on feeder lambs for a period of several months."

From the results obtained in the tests

Table 2.—Food consumption, weight gains and per cent sheep-tick control on treated and untreated feeder lambs. Scottsbluff, Nebraska, 1947–1951.

Method of Application and Treatment	1947–48			1948–49			1950–51		
	Per Cent Tick Increase or Decrease[1]	Mean Daily Gain in Lbs.	Lbs. Feed per 100 Lbs. Gain	Per Cent Tick Increase or Decrease[1]	Mean Daily Gain in Lbs.	Lbs. Feed per 100 Lbs. Gain	Per Cent Tick Increase or Decrease[1]	Mean Daily Gain in Lbs.	Lbs. Feed per 10 Lbs. Gain
Pen-Sprayed									
DDT—2 lbs./100 gals. H_2O	+39.1	0.32	938	+20.6	0.30	1207			
Sulfur—10 lbs./100 gals. H_2O	+32.5	0.34	889	+43.6	0.26	1315			
DDT—2 lbs., Sulfur—10 lbs. per 100 gals. H_2O	−35.0	0.34	914	+53.8	0.22[2]	1582	+42.8	0.32	979
Rotenone—6 oz./100 gals. H_2O	+12.5	0.33	876						
Rotenone—6 oz. Sulfur—10 lbs./100 gals. H_2O	+17.0	0.34	904						
Ribbon-Sprayed									
DDT—2 lbs. Sulfur—10 lbs. per 100 gals. H_2O				−30.8	0.29	1267	+51.5	0.28	1036
Rotenone—6 oz./100 gals. H_2O							+82.1	0.30	960
Dipped									
DDT—2 lbs. Sulfur 10 lbs. per 100 gals. H_2O				−97.1	0.27	1343	−100.0	0.30	986
Dusted									
Rotenone—5.0 per cent in Sulfur							−66.6	0.30	927
Not Treated	+41.9	0.29	955	+48.5	0.27	1412	+23.8	0.29	954

[1] Plus indicates an increase, minus a decrease (based on initial and final counts).
[2] This pen went off feed for several days.

reported here and those recorded by Schwardt & Matthysse, it appears that dipping is the most efficient method of insecticide application. Data cited in the present study indicate that dusting is more effective than the tested spray methods, but additional studies should be conducted to verify this finding.

COMPARISON OF INSECTICIDE EFFICIENCIES.—Many chemicals have been found effective for the control of sheep-ticks. Swingle in 1915 found that crude carbolic acid and two commercial materials would give control if used in three dippings at 14-day intervals. Other effective insecticides reported are nitrobenzene by Moore (1916), pyrethrum by Pettit (1934), wettable sulfur by Strong (1937), rotenone by Wille *et al.* (1937), bentonite sulfur by Mohler (1939), DDT by Cobbett & Smith (1945), benzene hexachloride by Slade (1945), chlordane by Knipling (1947) and methoxychlor, TDE and toxaphene by Fairchild *et al.* (1949). The comparative effectiveness of insecticides in sheep-tick control has also been widely tested. A few of the more important comparative tests are those reported by Schwardt & Matthysse (1948), Heath (1946), Graham & Scott (1948), Fairchild *et al.* (1949), Dicke *et al.* (1949), Gjullin (1949) and Hoffman (1949). The latter worker made his studies on the pupae alone. Most of the comparative studies were conducted under field conditions and indicated that at concentrations of 0.2 per cent or greater, all tested insecticides were effective. Gjullin from laboratory studies reported that parathion, dieldrin, heptachlor, aldrin and gamma benzene hexachloride were more effective than DDT, TDE, methoxychlor, chlordane, toxaphene and rotenone.

In the Nebraska tests an attempt was made to compare the effectiveness of DDT, rotenone, sulfur and various combinations of these insecticides. Results are given in table 1. It is readily seen from the tabulated data that a comparison of insecticidal efficiencies is affected by factors other than the effectiveness of the chemicals. This is borne out by the studies of Graham & Scott (1948) who stated that the variability of results indicated the importance of considering host-parasite relationships, wool length, period of immersion and methods of application in studies of comparative insecticidal efficiency. Although the importance of all factors cannot be overlooked, it would appear that methods of application and host-parasite relationships are most important. In the present tests chemical efficiency is masked by the lack of effectiveness of certain methods of application. Differences in the results obtained with pen-spraying and ribbon-spraying in the 1948–49 and 1950–51 tests indicate

the host-parasite relationship problem.

EFFECT OF PARASITE ON HOST.—Acceptance of parasite control measures and the success of control programs are directly dependent on economics. In the case of the sheep-tick much has been claimed concerning its economic importance. Imes (1917) reported that blood and lymph feeding by ticks reduced vitality and wool growth, caused poor feed consumption, and resulted in weight loss. Knowles (1918) stated that ticks destroyed wool fat. Mason (1921) mentioned ticks as affecting tanners and felt mongers. Hoare (1922) demonstrated that sheep-ticks transmitted the sheep trypanosome which now is believed to be harmless under normal conditions. Imes (1917) estimated an annual loss due to sheep-ticks of 20 cents per ewe and 25 cents per lamb. These figures were also cited by Edwards (1940). Schwardt & Matthysse (1948) reported lambs apparently killed by heavy tick infestations and mechanical damage to wool by the scratching and biting of infested animals. These workers also reported a reduction in wool quality due to tick excrement and debris. Another aspect of tick damage was reported by Bosman *et al.* (1950). According to their findings tick damage was low in well-fed Merino sheep, but poorly fed sheep were readily susceptible to the parasite with a resulting reduction in yield and grade of wool. Despite all claims little or no experimental information is available on comparative wool or weight differences between infested and non-infested sheep.

In the tests reported here an effort was made to collect data on weight losses due to tick infestations. To do this each sheep was carefully weighed twice at the beginning of each experiment and twice at the end. Weight gains were then computed for each animal and mean weights per lot were determined. Table 2 gives the mean weight gains for comparable lots during the three years of experiments. As can be seen from these data, no significant difference in gain was obtained following the control of ticks. It is true that the tick infestations involved were not excessive. On the other hand, it would seem not unreasonable to expect some slight losses even from light infestations of a parasite reported to be economically important.

The absence of any apparent injury during these tests seems to confirm the findings of Bosman *et al.* (1950), for all lambs used in the present study were maintained on what should be considered adequate balanced rations.

SUMMARY.—Sheep-tick infestations on feeder lambs were adequately sampled with ten evenly spaced 12-inch partings of the wool on each side of the animals. Dipping was found to be more efficient than pen-spraying or ribbon-spraying as a method of insecticide application. Power dusting also appeared to be more effective than spraying but not equal to dipping. Attempts to compare insecticidal efficiencies failed. Weight gain differences between infested and non-infested sheep could not be demonstrated.

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Fruit Fly Control in Hawaii with Poison-Bait Sprays Containing Protein Hydrolysates

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Preliminary tests in Hawaii with insecticidal sprays supplemented with sugar and certain protein hydrolysates have shown that their deposits are highly effective in attracting and killing the oriental fruit fly, *Dacus dorsalis* Hendel, and the Mediterranean fruit fly, *Ceratitis capitata* (Wied.).

Bait sprays containing sugar and parathion wettable powder, as recommended by Myburgh & Stubbings (1950) for use against fruit flies in South Africa, proved ineffective against the oriental fruit fly in small plot tests conducted by Steiner & Hinman (1952). Furthermore, laboratory tests indicated that the toxicity to the oriental fruit fly of deposits from most insecticides was reduced when sugar was included in the spray mixture. The potential usefulness of certain enzymatic yeast or soy hydrolysates in bait sprays was indicated in cooperative studies conducted by the University of California Agricultural Experiment Station,[2] which showed that these materials contain elements essential to the normal development of the oriental fruit fly, and by subsequent observations which demonstrated that the flies are strongly attracted to these proteins.

METHODS AND MATERIALS.—The experimental bait sprays were first compared by applying them to terminals or to small areas of guava foliage as concentrated sprays or dips. Shallow screen-bottomed trays, each measuring 3 by 3 feet, were placed underneath the treated foliage to catch the poisoned flies. The effectiveness of the sprays was gauged by comparing the number of dead flies found on these trays. Experiments were usually replicated five times each. Most of them

[1] The writer was assisted at various times during these investigations by Richard Nakamura, Frank Morishita, and Lawrence Kang.

[2] Unpublished results of studies made by Glenn L. Finney and Kenneth S. Hagen.

were conducted at sites along or just below the rim of a small gulch containing about 10 acres of guava trees, the fruit of which was infested with both oriental and Mediterranean fruit flies. In addition several small- and large-plot field tests of the usual type were made in guava, mango, and banana areas with mist-blower and conventional high-pressure sprayers.

The tray method of measuring results proved to be unsuitable for slow-acting poisons such as dieldrin, aldrin, DDT, chlordane, and nicotine bentonite in bait sprays, because many of the flies consuming the spray residues of these materials fell outside the trays or flew away, possibly dying elsewhere. After quick-acting poisons had weathered, they also were slow enough in their action to permit some flies to escape from the trays; hence comparative tests were usually terminated after 7 to 10 days.

The quick-acting poisons tested included Metacide, compound 22008 (3-methyl-1 phenyl-5-pyrazolyl dimethylcarbamate) dissolved in isopropyl alcohol and emulsified with Triton B-1956, a wettable powder containing 25 per cent of EPN, and wettable-powder and emulsifiable formulations containing 25 per cent of parathion and lindane. Each of these insecticides acted rapidly enough to paralyze flies after 1 to 3 minutes of feeding on the bait spray residues. The protein compounds used in the sprays included a proprietary protein hydrolysate described by the manufacturer as "freely soluble enzymatic hydrolysate of primary grown brewers' type nutritional yeast containing free amino acids, polypeptides and all factors of vitamin B complex," another proprietary yeast hydrolysate of similar composition (70 per cent of protein and 6 per cent of amino nitrogen), a soy hydrolysate from the same manufacturer containing less protein and amino nitrogen, and USP brewers' yeast.

RESULTS.—*Tray Tests.* Preliminary tests showed immediately that a concentrated spray containing protein hydrolysate, brown sugar, and Metacide attracted more than twice as many female oriental fruit flies as formulations containing only brown sugar and the insecticide or only the protein and the insecticide.

The metacide formula was less effective in attracting and killing flies than parathion (Table 1) where 15 ml. of spray was used on approximately 3 square feet of dense guava foliage in three locations. The residues of each, however, were attractive to the flies for about 7 days. The excessive amount of emulsifier in the metacide apparently made it ill-suited for concentrated spray use, causing enough run-off to reduce the amount of attractant deposited. The failure of the DDT formulas to kill flies quickly enough so that they would fall on the trays was typical of the slow-acting poisons, but this was not the only explanation for the poor results with DDT. Flies were attracted to the parathion and Metacide formulas from distances in excess of 50 feet, whereas few flies were seen around the DDT-sprayed foliage.

In additional tests conducted from June to November 1951, 25 guava leaves on 1 or 2 terminals over each of 5 trays per treatment were dipped in a well-agitated spray suspension. Representative results are given in table 2. Probably because of run-off and lower concentrations than those used previously, the deposits failed to remain highly attractive for more than 3 to 5 days; concentrated sprays usually were effective for at least 7 days. The maximum attraction occurred immediately after most of the water had evaporated, usually from 15 to 30 minutes after the application, and it diminished as deposits lost their tackiness during the ensuing week. As many as 3 flies per leaf were taken during the first hour after treatment at locations where few flies could be found before treatment. Approximately 62 per cent of all flies taken during the 7-day test periods appeared within 1 day after treatment and usually fewer than 10 per cent of them were taken after the third day.

The bait-spray deposits were easily washed off by rain, but light showers that did not completely wet the treated foliage were sometimes followed by increased catches. This was probably because the flies were able to consume lethal doses before they were affected by the toxicant. Both parathion and lindane 25 per cent wettable-powder formulations at the rate of one ounce per gallon of water were toxic enough to kill flies after 1 week, when a sugar-protein mixture was applied over the old residues on the seventh day. Apparently the length

Table 1.—Numbers of dead *Dacus dorsalis* flies caught in trays under guava foliage after it had been treated with poison-bait sprays. August 1950.

TREATMENT (CONCENTRATION IN 25% RAW SUGAR SOLUTION)	DAYS						TOTAL
	1	2	3	4	7	10	
Protein hydrolysate, 5%, plus—							
Metacide, 3%	173	84	34	9	42	0	342
Parathion 25 WP, 4%	196	166	154	8	514	2	1003
DDT 50 WP paste, 10%	23	0	1	2	1	0	27
DDT 50 WP paste, 10%	1	0	0	0	0	0	1
Untreated	1	3	0	0	1	0	5

of the effective period was limited more by loss of the attractant than by loss of the insecticide. In the experimental gulch the number of flies killed per 25 treated leaves during the first week after each treatment exceeded the number caught per standard glass invaginated trap baited with a fermenting sugar-yeast-vinegar bait.

The results in table 2 indicate that freshly prepared bait sprays (A-1 and A-3) were far superior to those in which fermentation had started (A-2 and A-4), and that the soy and protein hydrolysates were equally effective as attractants. A subsequent test (B) indicated that soy hydrolysate was only half as effective as protein hydrolysate, and that further comparisons of these two products are needed. Yeast hydrolysate, in these and more recent tests, was equal to the protein hydrolysate in attractiveness. Brewers' yeast (results not tabulated) was found to add little if any attractiveness to that obtained with sugar alone. Test C demonstrated the value of combining the sugar and soy hydrolysates, the kill of oriental fruit flies being about equal to the sum of the kills with the two materials when they were used separately.

In comparison with test D-4 a five-fold increase in the amount of parathion (D-1) significantly reduced the catch and an increase in sugar (D-2) had little beneficial effect. An increase in protein (D-3) produced highly significant increases in catches of both the oriental and Mediterranean fruit flies. This test indicated, as did test E, that the amount of parathion in most of the sprays used in earlier tests may have been excessive. Test E, which was run twice over two 7-day periods, indicated also that the type of sugar was probably of little importance.

In other tests emulsifiable formulations of parathion and compound 22008 in

Table 2.—Fruit flies caught on trays under guava foliage dipped in bait sprays. 1951.

TEST NO.	MATERIALS (OUNCES PER GALLON)			NUMBER OF FLIES	
	Hydrolysate	Sugar	Insecticide	*Dacus dorsalis*	*Ceratitis capitata*
A-1	Protein, 0.5	Raw, 4	Parathion 25 WP, 1	214	49
2	Same as A-1 except mixed 48 hours before use.			53	5
3	Soy, 0.5	Raw, 4	Parathion 25 WP, 1	201	44
4	Same as A-3 except mixed 48 hours before use.			33	15
B-1	Soy, 1	Raw, 5	Parathion 25 WP, 1	129	22
2	Protein, 1	Raw, 5	Parathion 25 WP, 1	212	17
3	Yeast, 1	Raw, 5	Parathion 25 WP, 1	228	28
C-1	Soy, 1		Parathion 25 EM, 2	167	21
2		Raw, 8	Parathion 25 EM, 2	163	19
3	Soy, 1	Raw, 8	Parathion 25 EM, 2	309	12
D-1	Protein, 0.15	Raw, 0.75	Parathion 25 WP, 1.5	56	11
2	Protein, 0.15	Raw, 3.75	Parathion 25 WP, 0.3	188	10
3	Protein, 0.75	Raw, 0.75	Parathion 25 WP, 0.3	249	67
4	Protein, 0.15	Raw, 0.75	Parathion 25 WP, 0.3	131	25
E-1	Protein, 1	Raw, 5	Parathion 25 WP, 0.25	182	10
2	Protein, 1	Raw, 5	Parathion 25 WP, 1	172	14
3	Protein, 1	Dark brown, 5	Parathion 25 WP, 1	149	14
4	Protein, 1	Granulated, 5	Parathion 25 WP, 1	174	11
5	Protein, 1	White corn syrup, 5	Parathion 25 WP, 1	178	10

protein-sugar bait sprays gave comparable results. The former was as effective as a wettable-powder formulation of parathion, but the emulsion tended to separate from the sugar-protein mixture, causing excessive deposits of parathion. Emulsifiable lindane was less than 10 per cent as effective as emulsifiable parathion in yeast hydrolysate-sugar formulas.

The bait sprays appeared to be more attractive to the females than to the males, since in tests with more than 40 formulas, including those listed in table 2, 69 per cent of the oriental fruit flies and 72 per cent of the Mediterranean fruit flies caught were females. Melon flies with the sexes equally divided appeared on the trays occasionally, and many were seen to feed on the residues and succumb. They also responded to higher concentrations of sugar more than the other species.

From July through October 1951, when most of the tray tests were conducted, less than 1 parasite per 500 flies was taken on the trays. The parasitization of flies reared from guava samples taken from 9 locations each week increased from 47 per cent in July to 74 per cent in September. The dominant parasite was *Opius oophilus* Fullaway, but *O. longicaudatus* Ashm. and *O. vandenboschi* Fullaway were also present.

The ratio of oriental fruit flies to Mediterranean fruit flies in gauva fruits collected in the gulch, where the single guava branch tests were conducted, was 2 to 1 in July, 13 to 1 in August, and 26 to 1 in September. The indications were that a greater proportion of the Mediterranean fruit flies emerging in the gulch were attracted to the bait sprays than was the case with the oriental fruit fly, since the former constituted 13 and 10 per cent, respectively, of the August and September catches. The bait sprays were attractive to sexually immature as well as gravid females of both species.

FIELD-PLOT TESTS.—In small-plot experiments the oriental fruit fly infestation index (larvae reared per pound of fruit) in a 1.25-acre plot of bananas sprayed with 12 ounces of protein hydrolysate, 7.5 pounds of raw sugar, and 2 pounds of parathion 25 per cent wettable powder per acre in 25 gallons of water averaged 93 per cent less than in unsprayed plots 7 and 14 days after each of 5 sprays. Parathion 25 per cent and DDT 50 per cent wettable powders, each applied at the rate of 6 pounds per acre without protein or sugar, gave only 80 to 82 per cent reductions on nearby 0.25-acre plots, each treatment being replicated 4 times. The unsprayed ripe fruit on similarly replicated plots averaged 14 larvae per pound on the 10 sampling dates. All the sprays were applied with mist-blower equipment.

In a commercial mango planting on Molokai, in 0.5-acre plots, with 2 replicates of each treatment, parathion 25 per cent wettable powder applied at the rate of 12 pounds per acre in 35 gallons of water gave an 89 per cent reduction in infestation, whereas a bait spray consisting of protein hydrolysate 0.5 pound, raw sugar 6 pounds, and parathion 25 per cent wettable powder at the rate of 6 pounds per acre in 17.5 gallons of water applied to one side of each tree gave only 72 per cent control. The unsprayed plots averaged 8 larvae per pound of fruit. In these tests all mature fruit was picked and sampled 4 times at 3- to 4-day intervals following each of the 4 sprays. The infestation indices on which control was based represented the means of 32 fruit samples varying from 6 to 10 pounds.

Where 6 sprays were applied at 2-week intervals to 0.33-acre guava plots each containing five replicates, parathion 25 per cent wettable powder at the rate of 8 pounds per acre in 350 gallons of water gave 98 per cent control, whereas a bait spray containing 4 pounds of parathion 25 per cent wettable powder, 10 pounds of raw sugar, and 2 pounds of protein hydrolysate in 350 gallons of water gave only 80 per cent control. However, the bait spray was applied to only the three sample guava tres in each replicate plot, so that only slight fumigating action was obtained from the 0.5 ounce of parathion used. The conventional spray was applied to all vegetation, so that a very substantial fumigating effect from the 10 ounces used per replicate aided in control.

The results of the small-plot experiments are believed to underestimate the over-all effectiveness of bait sprays, because of the attraction such sprays have on the populations in adjacent unsprayed plots and those sprayed with other materials.

Guava areas of 5 acres or more in several semi-isolated gulches bordered by pineapple fields were sprayed in 1950 and early in 1951. The gulches were 50 to 100 feet deep and 200 to 400 feet wide, and the sprays, which were applied from the rims of the gulches, rarely reached out more than 50 feet except when aided by air movement. The deposits were mostly on the upper surfaces in the upper part of the foliage.

The 1950 tests were not replicated nor were any untreated plots available. Performance was evaluated by comparing the mean post-treatment infestations with the respective pretreatment levels. The latter averaged 15 larvae per pound of fruit for each of the 2 treatments. Three sprays were applied at 2- to 3-week intervals. Parathion 25 per cent wettable powder alone, at the rate of 1.5 pound in 10 gallons of water per acre, effected a 63 per cent reduction in infestation compared with 83 per cent for a spray containing only 0.75 pound of parathion but supplemented with 8 pounds of raw sugar and 0.3 pound of protein hydrolysate in 6 gallons of water per acre. Both sprays were applied at a pressure of 600 pounds per square inch with a single gun, from a moving vehicle, at the rate of nearly 2 acres per minute.

In the 1951 tests, where 2 gulches were used for each of 2 treatments and 3 comparable nearby untreated gulches were reserved for comparison, 3 sprays were applied with a mist blower at 3-week intervals. Three 50-fruit samples were taken from areas along the bottom of each gulch at weekly intervals after each spray. The total number of samples was 27 per gulch. The mean infestation in the unsprayed gulches averaged 19 larvae per pound. DDT 50 per cent wettable powder at the rate of 3 pounds per acre in 8 gallons of water gave 82 per cent control compared with 87 per cent where parathion 25 per cent wettable powder at the rate of only 1 pound supplemented with 5 pounds of raw sugar and 4 ounces of protein hydrolysate in 4 gallons of water was used, and 94 per cent where a similar parathion-sugar spray with 8 ounces of soy hydrolysate was used. Application and material costs for the parathion-bait sprays averaged less than $1 per acre per week.

The tests conducted in the semi-isolated gulches in which reductions of 83 to 94 per cent were obtained from the application of bait sprays containing only 3 to 4 ounces of actual parathion per acre at about 3-week intervals, suggest that the bait sprays may be far more useful in large-area operations than in small areas subject to reinfestation. They also suggest that this type of spray may give good protection for longer periods than indicated by the results reported in table 2.

The fact that complete coverage is much less essential with bait sprays than with sprays that depend upon their residual contact action suggests that it may be possible to obtain good control of oriental and Mediterranean fruit flies with applications to the nonfruiting areas of the host plant only. Further studies are needed to develop information on this type of application. Where less spray is applied to the fruit, the parasites would also have a much better chance of escaping lethal exposures to the insecticides. The parasitization of fruit flies in the gulches sprayed with DDT averaged 42 per cent compared with 76 per cent in gulches where the parathion-bait spray was used and 62 per cent in untreated gulches.

SUMMARY.—Enzymatic protein hydrolysates of soy or yeast greatly increased the attractiveness of bait sprays containing sugar and parathion or Metacide to the oriental fruit fly, *Dacus dorsalis* Hendel, and the Mediterranean fruit fly, *Ceratitis capitata* (Wied.). Wettable-powder formulations of EPN and lindane and an emulsifiable formulation of compound 22008 (3 methyl-1 phenyl-5 pyrazolyl dimethylcarbamate) were also very effective as bait sprays when supplemented with sugar and protein hydrolysate.

Replicated tests in which small areas of guava foliage were treated and 3-by-3 foot trays were used to catch the dead flies indicated that such sprays were most effective while the deposits were drying. About 62 per cent of all flies attracted to dilute bait sprays applied to guava foliage appeared during the first day and less than 10 per cent after the third. However, good catches were made for as long as 7 days where concentrated bait sprays were applied. Maximum attraction was associated with tacky type deposits. Since the bait sprays containing

protein hydrolysate attracted flies for distances of at least 50 feet, less thorough coverage was required than when conventional residual-type sprays were used. The bait sprays were also less harmful to parasites. Deposits from slow-acting poisons, such as DDT, dieldrin, aldrin, chlordane, and nicotine bentonite, failed to kill flies rapidly enough for reliable evaluation of their effectiveness by the methods used.

In small-plot tests bait sprays containing protein hydrolysate, sugar, and parathion gave excellent oriental fruit fly control on bananas and good control on mangoes and guava. The effectiveness of the sprays lasted for 2 to 3 weeks after each application. In semi-isolated guava gulches average reductions of 87 to 94 per cent of the larvae were obtained with 4 ounces of parathion per acre, when this material was applied at 3-week intervals in a protein-sugar bait spray. The cost of the treatment was less than $1 per acre per week. DDT alone applied at the rate of 1.5 pound of toxicant per acre gave 82 per cent control.

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Response of Certain Insects to Plants Grown on Varying Fertility Levels[1]

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Many variations in abundance of insects have been attributed to soil conditions, particularly to fertility levels or to deficiencies of certain major nutrient elements, but there seldom has been any experimental evidence in support of such conclusions. In recent years, however, a few workers have begun investigations on the relationship of soil nutrient elements to insect populations, and the results have been quite striking in some cases.

Haseman (1946) has probably been the leader in encouraging investigations along these lines. He has conducted greenhouse studies with grain aphids, chinch bugs, greenhouse white flies, greenhouse thrips, and Colorado potato beetles. The grain aphid, *Toxoptera graminum* (Rond.), was found to thrive on plants deficient in most of the important nutrient elements. However, the aphid could not survive when reared on plants deficient in nitrogen or iron. The chinch bug, *Blissus leucopterus* (Say), and the common greenhouse thrips, *Thrips tabaci* Lind., were definitely favored by plants deficient in nitrogen.

Barker & Tauber (1951a) could find no effect of several nutrient deficiencies in nasturtium plants on the developmental period of the green peach aphid, *Myzus persicae* (Sulz.).

Evans (1938) found that the cabbage aphid, *Brevicoryne brassicae* (L.), produced more offspring on cabbage plants high in nitrogen. Mumford (1930), working with the beet leafhopper, *Circulifer tenellus* (Baker), also was convinced that plant sap high in nitrogen was conducive to a higher rate of reproduction by these insects.

Maltais (1951) has shown a high nitrogen content of pea plants to be positively correlated with a high degree of susceptibility to the pea aphid, *Macrosiphum pisi* (Kltb.). Barker and Tauber (1951b) presented data indicating greater fecundity of pea aphids on pea plants growing on a complete nutrient diet than on plants deficient in N, P, K, Ca or Mg. These investigators also found that plants on a complete diet withstood pea aphid attack much better than plants on the deficient diets. On the other hand, some workers (Arant and Jones, 1951, and Davidson, 1925) have found certain aphids to be favored by plants low in nitrogen.

Rodriguez (1951) showed that the re-

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productive potential of the two-spotted spider mite, *Tetranychus bimaculatus* Harvey, was increased when grown on tomato plants with high nitrogen. Rodriguez's work, as well as that of Davidson (1925), and Garman & Kennedy (1949) revealed a higher reproductive rate of certain mites and aphids on generally high fertility levels as contrasted to low fertility levels. Many more references could be added, but in general highly differing results have been obtained with different insects and different host plants, in regard to the effect of various nutritional deficiencies.

The work reported in this paper was undertaken as an attempt to arrive at some definite conclusions on the relation of soil minerals and fertility levels to the abundance of certain insects. Specifically, insect-plant combinations were studied as follows: European corn borer, *Pyrausta nubilalis* (Hbn.) on corn plants; pea aphid, *Macrosiphum pisi* (Kltb.) on pea plants; and the potato aphid, *Macrosiphum solanifolii* (Ashm.) on potato plants. These insects were studied both in the greenhouse on plants grown in nutrient solutions, and in the field, where various fertilizer combinations were used. Variations in the nutrient elements, especially nitrogen, phosphorus, and potassium, were studied in regard to their affect on abundance of these insects.

POTATO APHID EXPERIMENTS.—Triumph potato plants were grown in water nutrient cultures, with the chemical diet altered to create plants deficient in nitrogen, phosphorus, potassium, sulfur, magnesium, and iron. One complete, balanced plant diet was always included in each test, and at times plants were grown on diets with excesses of certain individual nutrient elements. All treatments were replicated four times.

When the plants were several inches tall, and most of the deficiency symptoms could be observed, five immature potato aphids were placed on each plant. Only aphids which were within 24 hours of the same age were used. These aphids were allowed to grow and reproduce until the plants were quite heavily infested. Usually the aphids were able to complete between one and two reproductive cycles before it became necessary to terminate the experiment. On terminating the experiment, exact counts of aphids on each plant were obtained. Results of two greenhouse tests are summarized in table 1.

Table 1.—Potato aphid populations on potato plants grown in various nutrient solutions in a greenhouse.

PLANT DIET	CHANGE IN ELEMENTS FROM COMPLETE DIET (P.P.M.)	TEST 1 AVERAGE NUMBER OF NYMPHS PER ADULT	TEST 2 AVERAGE NUMBER OF APHIDS PER PLANT
Complete		11.6	266
Low K	208 to 8	10.0	232
Low P	165 to 9	17.0	285
Low N	134 to 16	13.0	292
Low S	65 to 1.5	14.7	250
Low Mg	49 to 2	8.6	250
Minus Fe	15 to 0	7.6	222
High N	134 to 268	15.3	242
L.S.D.—5%		N.S.	N.S.

All aphid counts were analyzed for variance and in no case was there a significant difference in aphid population among the various treatments. Thus it was concluded that deficiencies of the nutrient elements tested created severe deficiency symptoms in potato plants before any obvious effect was exerted on the normal growth and reproduction of potato aphids feeding on such plants.

To ascertain the relative amounts of the major nutrients in potato plants grown in nutrient solutions, tissue tests were made on plants grown for 26 days on a balanced diet and on diets deficient in nitrogen, phosphorus and potassium. The plants on complete nutrients had 4.7, 0.52 and 5.36 per cent of N, P and K, respectively. Plants on the three deficient diets had 3.02, 0.24 and 2.16 per cent of N, P and K, respectively.

Triumph potatoes were also used in field tests, which were conducted in 1950 and 1951. Infertile sandy loam soils were chosen in order to permit maximum control over soil fertility. Using commercial fertilizers, plots were set up to give deficiencies and excesses of nitrogen, phosphorus and potassium. Check plots were also included with no fertilizer and a balanced fertilizer. The plots were each 10 by 10 feet, and all treatments were replicated four times in a randomized complete block design.

A natural infestation of aphids was allowed to build up in the open plots. These plots were swept periodically with an insect net to follow the aphid population throughout the summer. Observations also were made on aphid reproduc-

Table 2.—Potato aphid populations on potato plants grown on various fertility levels in the field.

Fertilizer Treatment	1950		1951		
	Aphids per Sweep	Caged Aphids per 20 Leaves	Aphids Swept from Ten-Foot Row 7/19	8/16	Aphids per Cage
None	—	—	53	36	525
Complete	23	582	163	49	1669
Low N	24	93	54	38	556
High N	31	—	68	56	1600
Low P	30	310	180	50	1228
High P	22	—	33	64	—
Low K	23	705	162	48	1311
High K	24	—	34	56	—
Low Mg	28	—			
L.S.D.—5%	N.S.	N.S.	108	N.S.	N.S.

tion on caged potato plants in most of the plots.

The cages were 2 by 2 feet at the base and three feet high. They were covered with 36-mesh plastic screen which prevented entrance or departure of insects and allowed maximum lighting and aeration within the cage. When the plants began to show symptoms of the various fertilizer treatments, an equal number of potato aphids was placed in each cage. Aphid reproduction within the cages was determined after 8 weeks, either by counting the insects on 20 leaves per cage or by counting all those present within the cage. The use of cages in this study was considered valuable as known numbers of aphids were used for infestation, movement of the aphids was controlled, and the aphids were free to grow and multiply without large numbers being destroyed by parasites and predators.

Aphid counts obtained in the potato field tests are shown in table 2. Low aphid populations during the 1950 season resulted in poor counts in open portions of the plots. In 1951, counts revealed far more aphids on the larger plants early in the season. In this test the large plants were in those plots containing some nitrogen fertilizer. It was concluded that the major reason for heavy build up of aphids on these plots was due to the plants reaching the flowering stage at an earlier date. Migrating aphids were probably attracted to the flowering branches. Later in the season the aphid populations were found to be approximately equal on all plots. This might be attributed to a nutritional factor due to fertility, but was more likely a natural levelling off of population caused by insect enemies of the aphid.

Table 3.—Pea aphid populations on pea plants grown with various nutrient diets in a greenhouse.

Plant Diet	Change in Elements from Complete Diet (p.p.m.)	Test 1	Test 2	
		Aphids per Plant	Young per Adult	Adult Longevity (Days)
Complete		49.2	—	—
Low N	134 to 16	47.8	93.8	21.4
High N	134 to 268	83.8	86.3	20.7
Low P	165 to 7	34.4	—	—
Low K	208 to 8[1]	45.0	—	—
High K	208 to 416	65.4	—	—
L.S.D.—5%		N.S.	N.S.	N.S.

[1] Because of very poor plant growth, the potassium in low K diet was raised to 112 p.p.m. when aphids were introduced.

In the cage tests there was no significant difference in aphid populations on the various fertility treatments, though there appeared to be a trend toward retarded development on low nitrogen plots.

That fertility variations in the plots did exist as planned was indicated both by deficiency symptoms and a highly significant difference in potato yields between the different plots.

PEA APHID EXPERIMENTS.—In 1950 a greenhouse test was conducted with pea aphids on Perfection pea plants. The general design was similar to that used in the potato aphid tests. Treatments consisted of high and low levels of nitrogen, phosphorus, and potassium, plus a balanced diet for a check. Ten pea plants were placed in each water culture jar, with four jars per treatment. Ten immature aphids were placed on each jar and allowed to grow and reproduce until some of the plants became heavily infested with aphids. Counts of aphids per jar were then made and analyzed statistically for differences in reproductive capacity on the different nutrient diets. The results of this first test are shown in table 3. There was no significant difference in the number of aphids on the various diets, although there were generally more aphids on plants with high nitrogen diets.

Since there seemed to be a tendency for aphids to build up faster on plants growing on a high nitrogen diet, an experiment was designed to study just the one element. In this experiment, pea plants were grown in number two tin cans filled with white sand, using a drip type nutrient culture. Just two nutrient solutions were used, one high in nitrogen (268 p.p.m.) and one deficient in nitrogen

(16 p.p.m.). Two liters of each nutrient solution were allowed to pass through the cans daily. There was a total of six cans per treatment, each can containing three plants. When the plants were about three inches high, three adult aphids were placed on the plants in each can, and allowed to give birth to young for 36 hours. These young were allowed to reach the adult stage, at which time they were reduced to a constant number of six per can. The plants were then enclosed in fine mesh screen cages.

Every two days thereafter the young aphids were counted and removed. Records were also kept of the death of all adult aphids. These records, as summarized in table 3, gave information on the average fecundity of the aphids on each diet, as well as their average life span. When all the aphids had died, the pea plants were removed, dried, and analyzed for total nitrogen content.

There were no significant differences in either fecundity or longevity on the high and low nitrogen diets. The nitrogen analysis of the plants revealed a highly significant difference in total nitrogen content, with an average of 6.6 and 5.3 per cent on the high and low nitrogen diets, respectively.

This second pea aphid experiment in the greenhouse did not substantiate the results obtained with high and low nitrogen plant diets in the first test. Likewise, the fecundity data from the second test was not in agreement with the recently published work of Barker & Tauber (1951b).

Field tests with the pea aphid were similar to those conducted with the potato aphid. Aphid counts were made both in open plots and within cages. Pea aphid counts in the open portion of the plots were determined by beating the aphids from about 30 plants into a pan. The findings were recorded as aphids per plant. The aphids on the caged plants were determined at harvest time after killing them first with parathion dust.

Results of the field tests are shown in table 4. In neither of the cage tests was there any significant difference in aphid population on plants grown on the highly differing fertility levels. There was a significant difference in aphid populations on uncaged peas in 1950 but comparable fertility treatments in 1951 did not duplicate these findings. Migrating pea aphids showed no preference for plants grown under good fertility conditions as compared to stunted plants grown with deficient nutrients. However, plants fertilized heavily with a balanced fertilizer were able to withstand an aphid attack and produce a better yield than were plants grown on soil with inadequate nutrients.

Table 4.—Pea aphid populations on pea plants grown on various fertility levels in the field.

Fertilizer Treatment	1950		1951	
	Aphids per Plant	Caged Aphids per Plant	Aphids per Plant	Aphids per Cage
None	2.8	—	50	—
Complete	2.4	890	61	11,900
Low N	3.1	793	58	10,400
High N	2.9	—	88	—
Low P	2.7	1111	69	14,300
High P	3.5	—	83	—
Low K	3.8	1035	84	10,400
High K	3.0	—	82	—
L.S.D.—5%	0.7	N.S.	N.S.	N.S.

Corn Borer Experiments.—Two greenhouse experiments were conducted to determine whether deficiencies of various elements in corn plant diets would affect the growth rate or survival of corn borers feeding on such plants. Nutrient diets employed were deficient in nitrogen, potassium, or potassium and phosphorus. A balanced plant diet was included with each test. In the first experiment five replicates were used in a randomized complete block design while twelve replicates were employed in the second test when only two nutrient levels were considered. A 72-day variety of sweet corn was used in these tests.

Corn borer egg masses in the "blackhead" stage were placed in the whorl of each corn plant when the plants attained an extended height of 3 to 4 feet. Twenty-four hours later, counts were obtained of the number of hatched eggs per jar (2 plants per jar). Special precautions were taken to prevent migration of the borers from jar to jar. When the majority of the larvae had attained the fifth instar, the plants were removed and dissected. Records were made of larval survival and stage of development. The latter was measured by average larval weight and instar, as determined by head capsule size. A summary of the results is presented in table 5.

Larval survival averaged about 75 per cent, but in neither test was there any

Table 5.—Corn borer survival and development on corn plants grown in nutrient solutions in a greenhouse.

Plant Diet	Change in Elements from Complete Diet (p.p.m.)	Test 1		Test 2		
		Per Cent Survival	Average Instar	Per Cent Survival	Average Instar	Average Larval Weight (mg.)
Complete		76	4.9	76	4.4	30.4
Low N	134 to 20	72	4.4	—	—	—
Low K	208 to 18	78	4.4	—	—	—
Low P & K	165 to 208 to 16.5 & 20.8	—	—	71	4.2	25.6
	L.S.D.—5%	N.S.	0.3	N.S.	[1]	N.S.

[1] Significant at 5 per cent level by t test analysis.

significant difference between treatments. In each experiment, there was slightly faster larval growth on the balanced nutrient diet than on any of the deficient diets. The more rapid growth of borers on plants with a complete diet was indicated also by the average larval weight.

In 1950, a limited field test was conducted in which corn borer eggs in the blackhead stage were placed on a series of sweet corn plants growing on plots varying in fertility and pH level. Two fertility levels were employed, one fertilized heavily with phosphorus and potassium, and the other unfertilized or rated as low in phosphorus and potassium. These two fertility levels were established at three different levels of pH, ranging from quite acid to very slightly alkaline. Corn plant dissections, 29 days after egg placement, showed a slightly higher survival of borers on the low fertility plots, but the difference was not significant (see table 6). No difference in growth rate of the borers was detected.

A 1951 field test was set up wherein field corn was grown in fertility plots as follows: (1) balanced fertilizer, (2) no fertilizer, (3) low nitrogen, and (4) low potassium. Treatments were replicated four times in a randomized complete block design. When the corn in the balanced fertilizer plots was 48 inches in extended height, the plants were manually infested with corn borer egg masses in the blackhead stage. When the larvae neared maturity, the corn plants were dissected and records taken of larval survival and growth rate. Averaged results of these data are shown in table 6.

Table 6.—Corn borer survival and development on corn plants grown on various fertility levels in the field.

Fertilizer Treatment	1950		1951	
	Per Cent Survival	Average Instar	Borers per Plant	Average Instar
Low P & K	7.8	4.1	—	—
High P & K	5.0	4.0	—	—
None	—	—	0.3	4.1
Complete	—	—	1.9	4.5
Low N	—	—	0.4	3.7
Low K	—	—	1.6	4.6
L.S.D.—5%	N.S.	N.S.	1.3	N.S.

Unfortunately, plots which received little or no nitrogen were so infertile that the corn plants were extremely stunted and larval survival was very low on such plants. There was, however, no significant difference in larval growth rate on plants grown on the different fertility levels although the borers tended to develop more satisfactorily on plants grown on complete nutrient and low potassium diets. The borer development was good on the latter plant diet primarily because of the other elements present and not because of the potassium deficiency.

SUMMARY.—The experiments presented in this paper were carried out in an attempt to determine whether plant nutrient elements have any effect on abundance of certain plant-feeding insects. Insect-plant combinations studied were: European corn borer on corn plants; pea aphid on pea plants; and the potato aphid on potato plants.

Greenhouse tests gave no significant difference in reproductive capacity of the potato aphid on potato plants grown on high and low levels of nitrogen, phosphorus, and potassium. That deficiencies of the various elements did exist in the potato plants was shown by deficiency symptoms and quantitative chemical tests for the elements involved.

Field observations on the potato aphid were made both in cage tests, where the number and movemement of the aphids were controlled, and in uncaged plots. Two years of testing failed to reveal any significant difference in the reproductive capacity of the potato aphid on potato plants grown on various fertility plots. There was distinct evidence, however, that an influence upon early migration resulted since aphids showed preference for plants with the most vegetative growth and the most advanced maturity.

Greenhouse tests showed no significant difference in the reproductive capacity of pea aphids on pea plants grown on high and low levels of nitrogen, phosphorus, and potassium. One experiment devoted exclusively to the study of nitrogen revealed no difference in fecundity or longevity of the pea aphid on high and low levels of the element. Quantitative analyses showed that the plants on the high nitrogen diet had a higher proportion of nitrogen than did the plants on low nitrogen diet.

In field fertility plots with both caged and uncaged pea aphids, no differences in reproductive capacity of the aphids was observed. The tests indicated that small plants in uncaged plots attract and support as large an aphid population as do large succulent ones, up to the point at which death of the smaller plants occurs.

In greenhouse tests, European corn borer larvae showed slightly faster growth on plants having a balanced diet than on plants with distinct deficiencies of nitrogen, potassium, or potassium and phosphorus.

In a field test, where plants were infested manually, corn borer survival was better on vigorous plants than on small, nutrient deficient plants of the same age.

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Relative Toxicity of Furethrin, Its Natural Acid Isomer, and Pyrethrins to House Flies

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Among analogs of allethrin recently prepared in Japan was one containing the furfuryl group as the side chain in the cyclopentenolone component instead of the allyl group characteristic of allethrin. This ester had been named "furethrin." A laboratory sample of it was received, with a report on its method of preparation, by chemists in the Bureau of Entomology and Plant Quarantine, who then prepared another sample of the ester in essentially the same manner. A study was undertaken to determine the toxicity of both samples to house flies, *Musca domestica* L., relative to that of natural pyrethrins. The Bureau chemists also prepared the natural acid isomer, that is, the *d-trans* chrysanthemum monocarboxylic acid isomer, of furethrin. Because stereoisomeric differences in the acid component of pyrethroids may result in differences in the toxicity of the esters (Gersdorff and Mitlin 1952) and measurements of any specific relationships are therefore of interest, this isomer was included in the study.

MATERIALS.—The preparation and description of furethrin are given by Matsui *et al.* (1952). The Bureau's sample, a nearly pure preparation, was slightly yellowish and formed a clear, practically colorless liquid when incorporated in refined kerosene. The sample from Japan was dark brown and formed a cloudy, brownish liquid, from which a small amount of fine, brownish sediment separated in a day or so. This sample therefore was either less pure when prepared or had deteriorated in transit. The sample of the *d-trans* acid isomer was practically pure. In the sample of pyrethrins used as a standard, 52 per cent consisted of pyrethrin I and cinerin I (A.O.A.C. method).

PROCEDURE.—The materials were dissolved in refined kerosene. After preliminary tests, sprays were prepared to contain four concentrations of each material that would cause mortality of flies to fall in a range extending over the 50 per cent mortality point.

Knockdown and mortality were determined in tests by the turntable method. Six replications were made with each spray; approximately 100 flies, averaging 2 to 2½ days in age, were used in each test. All sprays were tested against the same populations of flies. When not in use, the sprays were kept in the dark at room temperature, and there was no evidence of deterioration in any of them in the 10-day period during which the tests were made.

To evaluate relative toxicity and determine the precision of the estimates, the mortality data were subjected to probit analysis by the maximum-likelihood method as described by Finney (1947).

MORTALITY AND KNOCKDOWN.—The mortality data are summarized in table 1. Knockdown of flies was complete for all sprays.

Table 1.—Mortality of house flies caused by furethrin, its *d-trans*(acid isomer, and pyrethrins in kerosene sprays.

MATERIAL	CONCENTRATION	MORTALITY IN 1 DAY
	mg. per ml.	per cent
Furethrin:		
Japanese sample	8	84.4
	4	57.9
	2	35.5
	1	19.8
Bureau's sample	8	94.0
	4	79.1
	2	52.4
	1	23.5
d-trans Acid isomer	4	90.5
	2	70.3
	1	47.3
	0.5	23.6
Pyrethrins	8	93.5
	4	77.6
	2	42.4
	1	22.8

Comparison of the mortality data shows pure furethrin to be as toxic as pyrethrins. As expected, the preparation from Japan is less toxic than the pure product. The *d-trans* acid isomer appears to be a little less than twice as toxic as furethrin.

EVALUATION OF RELATIVE TOXICITY.—The slopes of the individually fitted lines ranged from 2.03 ± 0.19 probits per

unit log concentration for the Japanese sample to 2.55 ± 0.22 for pyrethrins. A study of the experimental errors justified the fitting of parallel lines to the data. Therefore, a generalization procedure was used, the common regression coefficient being 2.30 ± 0.08. Heterogeneity between populations of flies had increased both departure from parallelism and residual heterogeneity; consequently, in the calculation of the standard error for this estimation allowance was made for this heterogeneity. A single factor (2.58) was used, which was obtained from pooling the individual chi-square values; it was also used in the calculation of all following standard errors.

The generalized equations showing the regression of mortality, expressed in probits, on concentration in milligrams per centiliter, expressed as logarithms, are as follows:

Furethrin:	
Japanese sample	$Y=2.3026X+1.6424$
Bureau's sample	$Y=2.3026X+2.0677$
d-trans Acid isomer	$Y=2.3025X+2.6138$
Pyrethrins	$Y=2.3026X+1.9642$

From these equations the median lethal concentrations (LC-50's) were calculated. Relative toxicity was calculated as the inverse ratios of LC-50's. The estimations together with their standard errors are given in table 2.

Table 2.—Toxicity to house flies of furfuryl analogs of allethrin as compared with pyrethrins.

MATERIAL	LC-50	RELATIVE TOXICITY
	mg. per ml.	
Furethrin:		
Bureau sample	1.877 ± 0.090	1.109 ± 0.075
Japanese sample	2.872 ± 0.128	0.725 ± 0.047
d-trans Acid isomer	1.087 ± 0.050	1.915 ± 0.127
Pyrethrins	2.082 ± 0.100	1.0

CONCLUSIONS.—Furethrin was as toxic to house flies as natural pyrethrins, and therefore, on the basis of the relative toxicity of allethrin and pyrethrins as determined by this method, one-third as toxic as allethrin. The Japanese sample of furethrin was about three-fourths as toxic as the pure product.

The *d-trans* acid isomer was about twice as toxic as furethrin. This was the same ratio of toxicity found for analogous esters with a similar configurational relationship—that is, one ester formed from the *d-trans* acid and the other from the mixture of *cis* and *trans dl* acids—when the cyclopentenonlone component contained the allyl instead of the furfuryl side chain (Gersdorff 1949).

Furethrin and its *d-trans* acid isomer also had high knockdown value.

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Synergists for DDT Against Insecticide-Resistant House Flies[1]

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In many situations in southern California, house-fly control is no longer practicable by the residual application of the commercially available insecticids which normally have been used for this purpose. These situations have resulted from the development, in the field, of house-fly strains resistant to insecticides including, among others, DDT, TDE, methoxychlor, BHC, lindane, toxaphene, chlordane, and dieldrin (March & Metcalf, 1949a, 1950).

One approach in attempting to solve this critical problem may be the development of materials which will reactivate the above insecticides against resistant house flies. In this regard a number of compounds have been reported in the recent literature as synergists for DDT against various insects. Ranganathan *et al.* (1949) reported that β-methyl anthraquinone, benzil, and *p*-benzoquinone were synergists for DDT against adult females of *Culex fatigans* Wied. We were able to show only slight indications, if any, of activity by the first two compounds in increasing the effectiveness of DDT against resistant house flies, however. Tests were also negative with a number of related compounds including tetrachloro-*p*-quinone, 2,6-dimethoxy-*p*-quinone, 5,6,7,8,9,9-hexachloro-5,8-methano-4a,5,8,8a-tetrahydro-1,4-naphthoquinone, and benzoin.

Lynn & Dieter (1949) found a synergistic effect by 2,4-dinitrophenols on DDT against the peach aphid, Mexican bean beetle larvae, and greenhouse red spider. In our tests the following phenols were ineffective in increasing the toxicity of DDT to resistant house flies: 2,4-dinitrophenol, 4,6-dinitro-*o*-cyclohexylphenol, and 4,6-dinitro-*o*-cresol.

The pyrethrins' synergist, piperonyl cyclonene, was shown by Perry & Hoskins (1950, 1951a, 1951b) to be effective in increasing the toxicity of DDT against resistant house flies. They showed that this increase in effectiveness was due to the inhibition by piperonyl cyclonene of the process of detoxification of DDT in resistant flies. The quantities of piperonyl cyclonene necessary to achieve this synergistic effect, however, are of such magnitude as to eliminate it from consideration for practical field use. In tests with piperonyl cyclonene-DDT mixtures, we found a low order of increased effectiveness (March & Metcalf 1950), but with other pyrethrins' synergists, we found no indications of increased effectiveness for mixtures of DDT and the following: piperonyl butoxide, N-isobutylundecylenamide, piperine alkaloid, sesamin, piperonal, safrole, isosafrole, di-*n*-propyl-2-methyl-6,7-methylenedioxy-1,2,3,4-tetrahydronaphthalene-3,4-dicarboxylate, and N-(2-ethylhexyl)bicyclo(2.2.1)-5-heptene-2,3-dicarboximide.

More recently, a number of compounds structurally related to DDT, as differentiated from the above compounds, have been reported to be DDT synergists. Riemschneider (1950) reported an increase in knockdown activity against *Melophagus ovinus* L. and *Drosophila melanogaster* M. by mixtures of DDT and 2,2-bis(*p*-fluorophenyl)-1,1,1-trichloroethane, 2,2-bis(*p*-ethylphenyl)-1,1,1-trichloroethane, 2,2-bis(3,4-fluoromethylphenyl)-1,1,1-trichloroethane, octachloro-4,7-endomethylene tetrahydrindene, and octachloro-endomethylene-trimethylcyclohexane. Dieter & Thiegs (1950) found a synergistic effect for 1,1-bis(*p*-chlorophenyl) ethane and DDT against Mexican bean beetle larvae, black bean aphid, red spider, and southern armyworm. A synergistic effect for DDT-methoxychlor combinations against both susceptible and resistant house flies was found by Sturdy (1950). Sumerford *et al.* (1951) investigated a series of eleven compounds structurally related to DDT and reported that bis(*p*-chlorophenyl) methyl carbinol (DMC) (compound 39, Table 1) was the most active synergist for DDT against resistant house flies. Limited field tests with a DDT-DMC combination did not appear to give satisfactory residual

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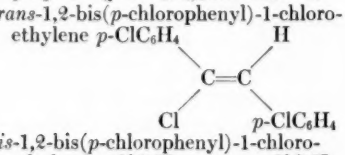
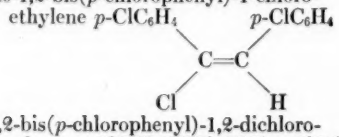
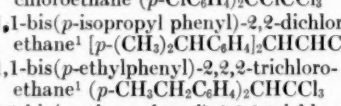
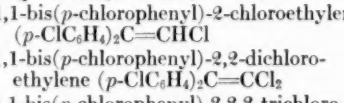
[2] The writers are indebted to the companies listed in the footnotes of table 1, and to Dr. F. A. Gunther of this station, for supplying many of the compounds used in both the laboratory and the field in accomplishing this study.

Table 1.—Relative synergistic activities for combinations of 5 parts DDT and 1 part of the following compounds.

COMPOUND	RELATIVE SYNERGISTIC ACTIVITY (ACTIVITY OF DDT ALONE = 1)
Halogenated hydrocarbons	
1. bis(*p*-chloro) biphenyl $(p\text{-ClC}_6\text{H}_4)_2$	1
2. bis(*p*-chlorophenyl) methane $(p\text{-ClC}_6\text{H}_4)_2\text{CH}_2$	20
3. bis(*p*-chlorophenyl) chloromethane[1] $(p\text{-ClC}_6\text{H}_4)_2\text{CHCl}$	140
4. diphenyl chloromethane[1] $(\text{C}_6\text{H}_5)_2\text{CHCl}$	2
5. bis(*p*-chlorophenyl) bromomethane $(p\text{-ClC}_6\text{H}_4)_2\text{CHBr}$	20
6. bis(*p*-methoxyphenyl) chloromethane $(p\text{-CH}_3\text{OC}_6\text{H}_4)_2\text{CHCl}$	1
7. bis(*p*-chlorophenyl) dichloromethane[1,2] $(p\text{-ClC}_6\text{H}_4)_2\text{CCl}_2$	4
8. triphenyl chloromethane[1] $(\text{C}_6\text{H}_5)_3\text{CCl}$	2
9. 1,1-bis(*p*-chlorophenyl) ethane[2] $(p\text{-ClC}_6\text{H}_4)_2\text{CHCH}_3$	100
10. 1-(*p*-chlorophenyl)-1-(*m*-chlorophenyl) ethane[2] $p\text{-ClC}_6\text{H}_4\text{CH(CH}_3\text{)-}m\text{-ClC}_6\text{H}_4$	20
11. 1-(*p*-chlorophenyl)-1-(*o*-chlorophenyl) ethane[2] $p\text{-ClC}_6\text{H}_4\text{CH(CH}_3\text{)-}o\text{-ClC}_6\text{H}_4$	4
12. 1,1-bis(*o*-chlorophenyl) ethane[2] $(o\text{-ClC}_6\text{H}_4)_2\text{CHCH}_3$	2
13. 1,1-bis(*p*-methoxyphenyl) ethane[1] $(p\text{-CH}_3\text{OC}_6\text{H}_4)_2\text{CHCH}_3$	2
14. 1,1-bis(*p*-chlorophenyl)-2,2,2-trifluoroethane $(p\text{-ClC}_6\text{H}_4)_2\text{CHCF}_3$	2
15. 1,1-bis(*p*-chlorophenyl)-1-chloroethane $(p\text{-ClC}_6\text{H}_4)_2\text{CClCH}_3$	60
16. 1,1-bis(*p*-dhlorophenyl)-1,2,2-trichloroethane[1] $(p\text{-ClC}_6\text{H}_4)_2\ \text{CClCHCl}_2$	4
17. 1,1-bis(*p*-chlorophenyl)-1,2,2,2-tetrachloroethane $(p\text{-ClC}_6\text{H}_4)_2\text{CClCCl}_3$	1
18. 1,1-bis(*p*-isopropyl phenyl)-2,2-dichloroethane[1] $[p\text{-}(\text{CH}_3)_2\text{CHC}_6\text{H}_4]_2\text{CHCHCl}_2$	2
19. 1,1-bis(*p*-ethylphenyl)-2,2,2-trichloroethane[1] $(p\text{-CH}_3\text{CH}_2\text{C}_6\text{H}_4)_2\text{CHCCl}_3$	6[3]
20. 1,1-bis(*p*-ethoxyphenyl)-2,2,2-trichloroethane[4] $(p\text{-CH}_3\text{CH}_2\text{OC}_6\text{H}_4)_2\text{CHCCl}_3$	>10[3]
21. 1,1-bis(*p*-chlorophenyl) ethylene $(p\text{-ClC}_6\text{H}_4)_2\text{C=CH}_2$	30
22. 1,1-bis(*p*-chlorophenyl)-2-chloroethylene $(p\text{-ClC}_6\text{H}_4)_2\text{C=CHCl}$	4
23. 1,1-bis(*p*-chlorophenyl)-2,2-dichloroethylene $(p\text{-ClC}_6\text{H}_4)_2\text{C=CCl}_2$	2
24. 1,1-bis(*p*-chlorophenyl)-3,3,3-trichloropropane[5] $(p\text{-ClC}_6\text{H}_4)_2\text{CHCH}_2\text{CCl}_3$	2
25. *trans*-1,2-bis(*p*-chlorophenyl)-1-chloroethylene 	1
26. *cis*-1,2-bis(*p*-chlorophenyl)-1-chloroethylene 	4
27. 1,2-bis(*p*-chlorophenyl)-1,2-dichloroethane $p\text{-ClC}_6\text{H}_4\text{CHClCHCl-}p\text{-ClC}_6\text{H}_4$	1
28. 1,2-bis(*x*-chlorophenyl)-propane[2] $x\text{-ClC}_6\text{H}_4\text{CH}_2\text{CH(CH}_3\text{)-}x\text{-ClC}_6\text{H}_4$	1
29. 1,3-bis(*p*-chlorophenyl)-2-methylpropane[2] $p\text{-ClC}_6\text{H}_4\text{CH}_2\text{CH(CH}_3\text{)CH}_2\text{-}p\text{-ClC}_6\text{H}_4$	3
Alcohols	
30. benzyl alcohol $\text{C}_6\text{H}_5\text{CH}_2\text{OH}$	1
31. *p*-chlorobenzyl alcohol $p\text{-ClC}_6\text{H}_4\text{CH}_2\text{OH}$	1
32. 1-*p*-chlorophenyl-2,2,2-trichloroethanol $p\text{-ClC}_6\text{H}_4\text{CHOHCCl}_3$	2
33. diphenyl carbinol $(\text{C}_6\text{H}_5)_2\text{CHOH}$	1
34. triphenyl carbinol $(\text{C}_6\text{H}_5)_3\text{COH}$	2
35. bis(*p*-chlorophenyl) carbinol $(p\text{-ClC}_6\text{H}_4)_2\text{CHOH}$	3
36. bis(*p*-fluorophenyl) carbinol $(p\text{-FC}_6\text{H}_4)_2\text{CHOH}$	1
37. bis(*p*-tolyl) carbinol $(p\text{-CH}_3\text{C}_6\text{H}_4)_2\text{CHOH}$	1
38. bis(*p*-methoxyphenyl) carbinol $(p\text{-CH}_3\text{OC}_6\text{H}_4)_2\text{CHOH}$	1
39. bis-(*p*-chlorophenyl) methyl carbinol[6] $(p\text{-ClC}_6\text{H}_4)_2\text{COHCH}_3$	60
40. bis(*p*-chlorophenyl) dichloromethyl carbinol $(p\text{-ClC}_6\text{H}_4)_2\text{COHCHCl}_2$	2
41. bis(*p*-chlorophenyl) ethyl carbinol[1] $(p\text{-ClC}_6\text{H}_4)_2\text{COHCH}_2\text{CH}_3$	4
42. bis(*p*-chlorophenyl) vinyl carbinol[1] $(p\text{-ClC}_6\text{H}_4)_2\text{COHCH=CH}_2$	40
43a. bis(*p*-chlorophenyl) ethynyl carbinol[7]	160
43b. bis(*p*-chlorophenyl) ethynyl carbinol[1] $(p\text{-ClC}_6\text{H}_4)_2\text{COHC}\equiv\text{CH}$	100
44. *o*-chlorophenyl-*p*-chlorophenyl ethynyl carbinol[1] 	3
45. bis(*o*-chlorophenyl) ethynyl carbinol[1] $(o\text{-ClC}_6\text{H}_4)_2\text{COHC}\equiv\text{CH}$	1
46. bis(2,4-dichlorophenyl) ethynyl carbinol[7] $(2,4\text{-Cl}_2\text{C}_6\text{H}_3)_2\text{COH}\equiv\text{CH}$	20
47. *p*-chlorophenyl phenyl ethynyl carbinol[1] 	4
48. bis(*p*-tolyl) ethynyl carbinol[1] $(p\text{-CH}_3\text{C}_6\text{H}_4)_2\text{COHC}\equiv\text{CH}$	2
Ethers	
49. 1-(α-methylbenzyloxy)-2-propanol[2] $\text{C}_6\text{H}_5\text{CH(CH}_3\text{)OCH}_2\text{CHOHCH}_3$	2
50. allyl benzyl ether[2] $\text{CH}_2\text{=CHCH}_2\text{OCH}_2\text{C}_6\text{H}_5$	1
51. dibenzyl ether $(\text{C}_6\text{H}_5\text{CH}_2)_2\text{O}$	2
52. bis(α-methyl benzyl) ether[2] $[\text{C}_6\text{H}_5\text{CH(CH}_3\text{)}]_2\text{O}$	1
53. bis(*p*-chlorobenzyl) ether $(p\text{-ClC}_6\text{H}_4\text{CH}_2)_2\text{O}$	2

Compound	Relative Synergistic Activity (Activity of DDT Alone = 1)
54. bis(*p*-chlorophenoxy) methane[2] $(p\text{-}ClC_6H_4O)_2CH_2$	2
55. 1,4-bis(2,4-dichlorophenoxy) butene-2[1] $2,4\text{-}Cl_2C_6H_3OCH_2CH{=}CHCH_2O\text{-}2,4\text{-}Cl_2C_6H_3$	2
56. 1-ethoxy-1-phenoxy-2,2,2-trichloroethane[8] $CH_3CH_2OCH(CCl_3)OC_6H_5$	2
57. 1-ethoxy-1-*p*-chlorophenoxy-2,2,2-trichloroethane[8] $CH_3CH_2OCH(CCl_3)O\text{-}p\text{-}ClC_6H_4$	2
58. 1-butoxy-1-*p*-chlorophenoxy-2,2,2-trichloroethane[8] $C_4H_9OCH(CCl_3)O\text{-}p\text{-}ClC_6H_4$	4
59. 1-hexoxy-1-*p*-chlorophenoxy-2,2,2-trichloroethane $C_6H_{13}OCH(CCl_3)O\text{-}p\text{-}ClC_6H_4$	4
60. bis(*p*-chlorophenyl) carbinol, methyl ether $(p\text{-}ClC_6H_4)_2CHOCH_3$	4
61. bis(*p*-chlorophenyl) carbinol, ethyl ether $(p\text{-}ClC_6H_4)_2CHOCH_2CH_3$	2
62. bis(*p*-chlorophenyl) carbinol, β-chloroethyl-ether $(p\text{-}ClC_6H_4)_2CHOCH_2CH_2Cl$	4
63. bis(*p*-chlorophenyl) methyl carbinol, methyl ether $(p\text{-}ClC_6H_4)_2C(CH_3)OCH_3$	60
64. di[bis(*p*-chlorophenyl) carbinol] ether $[(p\text{-}ClC_6H_4)_2CH]_2O$	1
65. di[bis(*p*-chlorophenyl) methyl carbinol] ether $[(p\text{-}ClC_6H_4)_2C(CH_3)]_2O$	80
Thioethers	
66. bis(*p*-chlorophenyl) sulfide $(p\text{-}ClC_6H_4)_2S$	2
67. *p*-chlorophenyl-*p*-chlorobenzyl sulfide $p\text{-}ClC_6H_4SCH_2\text{-}p\text{-}ClC_6H_4$	2
68. bis(*p*-chlorophenylmercapto) methane[9] $(p\text{-}ClC_6H_4S)_2CH_2$	30
69. 1,1-bis(*p*-chlorophenylmercapto) ethane[9] $(p\text{-}ClC_6H_4S)_2CHCH_3$	5
70. 2,2-bis(*p*-chlorophenylmercapto) propane $(p\text{-}ClC_6H_4S)_2C(CH_3)_2$	6
71. dibenzyl sulfide $(C_6H_5CH_2)_2S$	30
72. bis(*p*-chlorobenzyl) sulfide[4] $(p\text{-}ClC_6H_4CH_2)_2S$	80
73. bis(2,4-dichlorophenyl) sulfide[4] $(2,4\text{-}Cl_2C_6H_3)_2S$	2
74. bis(*p*-chlorobenzyl) disulfide[4] $(p\text{-}ClC_6H_4CH_2)_2S_2$	2
75. bis(2,4-dichlorobenzyl) disulfide[4] $(2,4\text{-}Cl_2C_6H_3CH_2)_2S_2$	4
76. 3,4-dichlorophenyl trichloromethyl disulfide[1] $3,4\text{-}Cl_2C_6H_3SSCCl_3$	2
Ketones	
77. bis(*p*-chloro) benzophenone $(p\text{-}ClC_6H_4)_2C{=}O$	3
78. bis(*p*-methoxy) benzophenone $(p\text{-}CH_3OC_6H_4)_2C{=}O$	1
Acid	
79. bis(*p*-chlorophenyl) acetic acid $(p\text{-}ClC_6H_4)_2CHCOOH$	2
Esters	
80. bis(*p*-chlorophenyl) carbonate $(p\text{-}ClC_6H_4O)_2C{=}O$	2
81. 1-*p*-chlorophenyl-2,2,2-trichloroethyl acetate $CH_3COOCH(p\text{-}ClC_6H_4)CCl_3$	2
82. 1-*p*-chlorophenyl-2,2,2-trichloroethyl butyrate $C_3H_7COOCH(p\text{-}ClC_6H_4)CCl_3$	2
83. 1-*p*-chlorophenyl-2,2,2-trichloroethyl caprylate $C_7H_{15}COOCH(p\text{-}ClC_6H_4)CCl_3$	2
Mixed	
84. bis(*p*-chlorophenyl) ethoxymethyl carbinol[10] $(p\text{-}ClC_6H_4)_2COHCH_2OC_2H_5$	3
85. *p,p'*-dichlorobenzilic acid, ethyl ester[10] $(p\text{-}ClC_6H_4)_2COHCOOC_2H_5$	10
Miscellaneous	
86. dibenzyl dithio-bis(dithioformate)[9] $(C_6H_5CH_2SC{=}S)_2$	2
87. bis(*p*-chlorobenzoyl) sulfide[9] $(p\text{-}ClC_6H_4C{=}O)_2S$	3
88. bis(*p*-chlorophenyl) sulfone $(p\text{-}ClC_6H_4)_2SO_2$	2
89. *p*-tolyl trichloromethyl thiosulfonate[1] $p\text{-}CH_3C_6H_4SO_2SCCl_3$	2
90. *p*-chlorophenyl-*p*-chlorobenzene sulfonate $p\text{-}ClC_6H_4SO_2O\text{-}p\text{-}ClC_6H_4$	2
91. bis(*p*-chlorophenyl) phosphate $(p\text{-}ClC_6H_4O)_2POOH$	1
92. bis(*p*-chlorophenyl) phosphinic acid[9] $(p\text{-}ClC_6H_4)_2POOH$	3
93. bis(*p*-chlorophenyl) ethylphosphinate[9] $(p\text{-}ClC_6H_4)_2POOCH_2CH_3$	2
94. 1-phenyl-3-methylpyrazolyl-(5)-dimethyl carbamate[10] $CH_3C_3HN_2(C_6H_5)OOCN(CH_3)_2$	4
95. N-phenyl-*p*-chlorophenyl carbamate $C_6H_5NCOO\text{-}p\text{-}ClC_6H_4$	1
96. 2,2-bis(2-chlorothienyl)-1,1,1-trichloroethane $(2\text{-}Cl\text{-}C_4H_2S)_2CHCCl_3$	1

[1] Rohm and Haas Company.
[2] The Dow Chemical Company.
[3] These compounds alone are more toxic than DDT to resistant house flies, which accounts for more than half of the activity indicated.
[4] Chemical Biological Coordination Center, National Research Council.
[5] Lubrizol Corp.
[6] The Sherwin-Williams Company.
[7] General Chemical Division, Allied Chemical and Dye Corp.
[8] Naugatuck Chemical Division, United States Rubber Company.
[9] Monsanto Chemical Company.
[10] Geigy Company, Inc.

control, however.

It is the purpose of this paper to present a comparison of the activities of ninety-six compounds, structurally related to DDT, as synergists for DDT against resistant house flies, and to present further studies including limited field trials with the most promising of those showing synergistic activity.

MATERIALS AND METHODS.—The com-

pounds investigated in this study were synthesized in our laboratories or obtained from commercial sources as noted in table 1. Comparisons of acaricidal and insecticidal activities for many of them have previously been published (Metcalf 1948).

Synergistic activities were evaluated by our standard procedures for the topical application of microdrops (March & Metcalf 1949a). Groups of twenty 3- to 4-day-old adult female house flies of the Super-Pollard strain[3] were individually treated with 1-mm.[3] drops of acetone solutions of DDT and the synergists, and mortalities were determined in 24 hours. All tests were accomplished in duplicate. All compounds were first examined at 50γ of DDT and 10γ of compound per female fly (1 mm.[3] of weight/volume acetone solution containing 5 per cent DDT and 1 per cent compound). Those combinations which gave 90 per cent or greater mortality at this level, compared with 20 ± 12 per cent mortality for 50γ of DDT alone, were re-evaluated at lower doses, retaining the DDT-synergist ratio of 5 to 1, respectively.

Residual-type tests were accomplished by depositing 1 ml. of acetone solution containing DDT or a DDT-synergist combination on 9-cm. filter paper in the bottom of a 9-cm. petri dish, so that 200 mg./ft.[2] of DDT and 40 mg./ft.[2] of synergist were deposited. The filter papers were allowed to dry for 24 hours, and then 20 adult female flies were introduced. Per cent knockdown was determined at intervals of 0.5, 1, 2, and 3 hours, at which times the flies were removed to clean cages and held for determination of 24-hour mortalities.

Field applications were carried out in a standard manner, using a high-pressure orchard-type spray rig and spray guns with No. 5 discs. All accessible surfaces on which flies were likely to rest were sprayed until the run-off point was reached.

DISCUSSION OF RESULTS.—*Initial Examination for Synergistic Activity.*—Relative synergistic activities against the Super-Pollard strain based on the activity of DDT alone as 1, are given in table 1 for combinations of DDT and the ninety-six compounds examined. Dosage-mortality data for combinations of DDT and the sixteen most active synergists are given in table 2.

Although the various series of analogues and homologues examined in this study are not complete, certain structural characteristics necessary for synergistic activity are apparent. The association of the bis(*p*-chlorophenyl) structure with synergistic activity can be seen from a comparison of the activities of compounds 3, 4, 6, and 8; 9, 10, 11, 12, and 13; 43, 44, 45, 46, 47, and 48; and 71 and 72, in which decreased activity results from the loss of the *p*-chloro substituents or substitution of methyl, methoxy, or *o*-, *m*-, and 2,4-dichloro substituents. The marked decrease in activity brought about by the shift of a single chloro substituent from *p* to *m* (9 and 10) and *p* to *o* (9, 11, 43, and 44) and by the loss of a single *p*-chloro substituent (43 and 47) is especially significant. The high activity of compound 71, which contains no *p*-chloro substituents, is an exception, although it fits the general pattern since it is less active than compound 72, which contains the bis(*p*-chlorophenyl) structure.

The central aliphatic group which links the two *p*-chlorophenyl groups is of even greater importance in determining activity, for many of the compounds which contain the bis(*p*-chlorophenyl) structure are inactive. The necessity for such a central aliphatic linking group is shown by compound 1, which is inactive. The central linking group can be altered within certain limits, however, while still maintaining synergistic activity. Of the sixteen most active compounds studied, fifteen contain the bis(*p*-chlorophenyl) structure. Of the sixteen, four contain simple aliphatic linking groups (2, 9, 10, and 21); three, halogenated aliphatic groups (3, 5 and 15); four, alcoholic groups (39, 42, 43, and 46); two, ether groups (63 and 65); and three, thioether groups (68, 71, and 72). Compound 71, which contains no *p*-chloro substituents, has been discussed above. Compounds containing ketone, acid, sulfone, sulfonate, phosphinate, phosphate, disulfide, and carbamate linking groups (74, 77, 79, 88, 90, 91, 92, and 95) exhibit at the most a low order of activity. Maximum activity is realized in each of the above groups by different though interrelated structures. The thioethers differ from the others in that the latter show maximum activity when the

[3] Developed from the Pollard strain (March & Metcalf 1949b) by further selection with lindane. Unless otherwise specifically noted, all house-fly tests were accomplished with this resistant strain.

Table 2.—Dosage-mortality data for graded combinations of DDT and the sixteen most active synergists, in constant ratio of 5 parts DDT to 1 part synergist.

	Synergist	Melting Point Uncorrected, °C.	24-Hour Per Cent Mortalities for Following Dosages of DDT-Synergist Combinations in γ/Female Fly				
			DDT	50	10	5	2.5	1.25
			Synergist	10	2	1	0.5	0.25
43a.	bis(*p*-chlorophenyl) ethynyl carbinol	61–73		100	100	100	98	96
3.	bis(*p*-chlorophenyl) chloromethane	60–62.5		100	100	100	88	68
9.	1,1-bis(*p*-chlorophenyl) ethane	53–54		100	100	100	85	52
43b.	bis(*p*-chlorophenyl) ethynyl carbinol	72.5–74		100	98	95	72	48
65.	di[bis(*p*-chlorophenyl) methyl carbinol] ether	83–85		100	100	90	75	38
72.	bis(*p*-chlorobenzyl) sulfide	41.5–42		100	98	98	62	35
15.	1,1-bis(*p*-chlorophenyl)-1-chloroethane	76–77		98	100	80		
63.	bis(*p*-chlorophenyl) methyl carbinol, methyl ether	83–84		100	98	72	48	32
39.	bis(*p*-chlorophenyl) methyl carbinol	70–71		100	78	55	48	30
42.	bis(*p*-chlorophenyl) vinyl carbinol	Liquid		100	90	62	22	18
21.	1,1-bis(*p*-chlorophenyl) ethylene	85–87		100	92	48	38	8
71.	dibenzyl sulfide	47–48		98	80	50	30	35
68.	bis(*p*-chlorophenylmercapto) methane	44–45		100	65	50	30	10
46.	bis(2,4-dichlorophenyl) ethynyl carbinol	Liquid		100	88	52	15	8
2.	bis(*p*-chlorophenyl) methane	54–55		100	65	28	25	10
10.	1-(*p*-chlorophenyl)-1-(*m*-chlorophenyl) ethane	Liquid		92	52	35	30	15
5.	bis(*p*-chlorophenyl) bromomethane	79–80		92	55	25	18	5

DDT (alone) 50γ/female fly 20 ± 12% mortality.
Synergists (alone) 10γ/female fly <10% mortality.

p-chlorophenyl groups are separated by a single carbon atom (2, 3, 9, 15, 21, 25, 26, 27, 28, and 29), as in DDT, whereas the thioethers show maximum activity by separation with —CH_2SCH_2— or —SCH_2S— groups (66, 67, 68, 72, and 74).

The simple aliphatic-linked series shows maximum activity with the 1,1-ethane linkage (9), compared with the methane (2) or unsaturated 1,1-ethylene (21) linkages. In general, increasing the size of the linking group by substitution of Cl for H, especially on the terminal carbon of the aliphatic chain, decreases activity (9, 15, 16, 17, 21, 22, and 23), although substitution of Cl for a single H in the methane linking group markedly increases activity (2 and 3). If both H's in compound 2 are replaced by Cl's, however, the resulting compound (7) is nearly inactive. Similarly substitution of a single Br for H produces an active compound (5), but a less active one than substitution by Cl (3). Substitution of F for H in the 2-position of compound 9 greatly decreases activity (14), although Metcalf (1948) showed that compound 14 closely resembles compound 9 chemically and in its acaricidal activity.

In the series with alcoholic groups maximum activity is found in the ethynyl carbinol linkage (43). Two samples of this compound (43a and b) from different sources were investigated. It is of interest that the less pure compound, as indicated by melting points, shows the greater activity. Progressive saturation of the ethynyl group to vinyl and ethyl decreases activity (41 and 42). Among the compounds in this series with saturated central linking groups, maximum activity is shown by the methyl carbinol (39), with the two adjacent homologues, the carbinol (35) and the ethyl carbinol (41), relatively inactive. Substitution of Cl for H in the aliphatic portion of the linking group decreases activity (39 and 40); increased substitution of Cl for H in the aromatic rings also decreases activity, though not to the same degree (43 and 46). Substitution of Cl for OH in compound 35 markedly increases activity (3), but effects no appreciable change in the next higher pair of homologues, the methyl carbinol (39) and the chloro ethanol (15), which are equally active.

Compound 65 which is the di-ether of compound 39 above, shows the maximum activity for the ether-linking-group series. In order for the ethers to show activity, the carbinols on which they are based must be active (35, 60, 61, 62, and 64 and 39, 63, and 65). Internal ether (—CH_2OCH_2—) or acetal (—OCH_2O—) linkages for the *p*-chlorophenyl groups

Table 3.—Dosage-mortality data for various ratios of DDT and synergists.

Dosage, γ/Female Fly		24-Hour Per Cent Mortalities for DDT Plus the Following Synergists			
DDT	Synergist	3	9	43a	43b
1	0.01	28	5	8	8
1	0.05	55	12	22	5
1	0.1	72	12	42	15
1	0.25	95	18	62	28
1	0.5	100	30	90	50
1	1.0	100	52	98	50
0.05	0.05	80			
0.02	0.02	5			
0.02	0.1	10			
0.02	0.2	45			
0.01	0.01	0			
0.01	0.05	0			

DDT, 1 γ/female fly 8±4 per cent mortality.
50 γ/female fly 11±4 per cent mortality.
Synergists, 50 γ/female fly <10 per cent mortality.

produce inactive compounds (53 and 54).

Maximum activity in the thioethers is obtained with the $—CH_2SCH_2—$ linking group (72), although the mercaptal group ($—SCH_2S—$) also produces an active compound (68). These two compounds are most interesting, since their O analogues (53 and 54) are inactive. The thioethers are also peculiar, since compound 71, the analogue of compound 72 containing no *p*-chloro substituents, is relatively active, whereas in the alchols the loss of a single *p*-chloro substituent from compound 43 produces a much less active compound (47). Increased substitution of Cl in the aromatic portion of the molecule, on the other hand, decreases activity to an even greater degree (73). Modifications of the linking group to —S—, $—SCH_2—$, $—SCH(CH_3)S—$, $—C(CH_3)_2S—$, or $—CH_2SSCH_2—$ also produce compounds of low activity (66, 67, 69, 70, and 74).

Further studies with additional homologues and analogues of these series of compounds will be necessary in order to formulate more specific relations of structure to activity. It is noteworthy that the majority of the compounds examined show considerable acaricidal activity but no appreciable insecticidal activity (Metcalf 1948), and that none of them when used alone, except 19 and 20, show any appreciable toxicity to resistant house flies at the 10γ/fly level.

Ratio of Synergist to DDT.—The effect of varying the ratio of synergist to DDT was determined for compounds 3, 9, 43a, and 43b. Dosage-mortality data for various ratios of the above synergists and DDT, from 1:100 to 10:1, are given in table 3. Synergistic activity increased in all cases as the ratio of synergist to DDT increased, but even with a 10:1 combination, it was not possible to reactivate DDT against resistant flies to its original activity against susceptible flies.

Separate Applications of DDT and Synergist at Various Time Intervals.—Results of separate applications of DDT and compounds 3 and 9 at various time intervals are given in table 4. These tests were accomplished, for example, by applying compound 3 (0.5γ in 1 mm.³ acetone /fly), followed by DDT (2.0γ in 1 mm.³ acetone/fly) immediately or with intervals of 0.5, 1, 2, 5, 14, or 24 hours between the two applications. Mortalities were determined 20 hours after application of the second compound. Synergistic activity was evident when either DDT or synergist was applied up to 24 hours after the other. When application of the syner-

Table 4.—Dosage-mortality data for separate applications of DDT and synergists at various time intervals.

Compound and Dosage	Per Cent Mortalities 20 Hours After Last Application						
	Hours Between Application of First and Second Compounds						
	0	0.5	1	2	5	14	24
DDT (2.0 γ/female fly)	38±6						
3 (0.5 γ/female fly)	2±1						
9 (0.5 γ/female fly)	0						
DDT then 3	100	100	100	100	100	100[1]	
3 then DDT	100	100	95	95	80	75	80
DDT then 9	95		100		80	90[2]	
9 then DDT	95		85		80		50

[1] 25 per cent of flies affected from DDT alone at 14 hours.
[2] 55 per cent of flies affected from DDT alone at 14 hours.

Table 5.—Dosage-mortality data for graded combinations of methoxychlor and synergists in constant ratio of 5 parts methoxychlor to 1 part synergist, and of a constant amount of methoxychlor and various amounts of synergists.

DOSAGE, γ/FEMALE FLY		24-HOUR PER CENT MORTALITIES FOR METHOXYCHLOR PLUS THE FOLLOWING SYNERGISTS			
Methoxychlor	Synergist	3	9	43a	43b
0.31	0.06	82	20	48	62
0.62	0.12	82	42	85	100
1.25	0.25	100	90	98	100
2.5	0.5	100	82	100	100
5.0	1.0	100	98	100	100
10.0	2.0	100	100	100	100
0.3	0.003	42	25	52	35
0.3	0.015	62	50	60	68
0.3	0.03	55	20	55	50
0.3	0.075	70	50	72	85
0.3	0.15	95	50	92	92
0.3	0.3	100	55	100	100

Methoxychlor, 0.3 γ/female fly 24±13 per cent mortality.
10 γ/female fly 76±4 per cent mortality.
Synergists, 50 γ/female fly <10 per cent mortality.

gist was followed by that of DDT, there was a progressive decrease in the 20-hour mortalities with increase in the interval between the two applications. This decrease in mortality was not evident when the order of application was reversed, however. This may be explained in part by the fact that DDT was acting over a longer period in those tests in which it was applied first, or by the possibility that when the synergist was applied first, it was partially excreted or degraded by the time the DDT was applied.

Synergism with Methoxychlor.—The synergistic effects of compounds 3, 9, 43a, and 43b with methoxychlor also were investigated. Dosage-mortality data for graded combinations of methoxychlor and synergist in a constant 5-to-1 ratio, and for a constant amount of methoxychlor (0.3γ/female fly) in combination with varying amounts of synergist, are given in table 5. Methoxychlor is more toxic than DDT to the Super-Pollard strain, but the effect of the synergists, though similar, was less for it than for DDT.

Table 6.—Dosage-mortality data for DDT alone and combinations of DDT and synergists 3 and 43a against a susceptible strain of flies.

DOSAGE, γ/FEMALE FLY		24-HOUR PER CENT MORTALITIES FOR		
DDT	Synergist	DDT Alone	DDT +3	DDT +43a
.01	.002	18	10	12
.02	.004	32	25	10
.03	.006	48	—	18
.04	.008	60	—	23
.05	.01	67	—	38

Activity of DDT-Synergist Combinations Against Susceptible House Flies.—The results of a series of experiments with DDT and combinations of DDT and compounds 3 and 43a against a susceptible strain are given in table 6. These two synergists showed no indications of increasing the activity of DDT against the susceptible strain, in contrast to the previously recorded activity against the resistant strain. In fact, they decreased the activity of the DDT. Perry & Hoskins (1951a) found both antagonistic and

Table 7.—Time of exposure to residual deposits of DDT and methoxychlor, alone and in combination with synergists, in relation to knockdown and mortality.

COMPOUND[1]	EXPOSURE PERIOD, IN MINUTES, REQUIRED FOR			
	50 Per Cent Knockdown		50 Per Cent Mortality in 24 Hours	
	Susceptible Strain	Resistant Strain	Susceptible Strain	Resistant Strain
DDT alone	120	173	20	>180 (5%)[2]
DDT+3		127		92
DDT+9		135		94
DDT+43a		113		120
DDT+43b		160		111
Methoxychlor alone	90	180	35	>180 (20%)[2]
Methoxychlor+3		86		77
Methoxychlor+9		100		87
Methoxychlor+43a		92		90
Methoxychlor+43b		96		100

[1] Residues contained 200 mg./ft.² DDT or methoxychlor and 40 mg./ft.² synergists.
[2] 24-hour mortality following 180 minutes exposure.

Table 8.—Relative resistance of house-fly populations from four field-trial locations, in comparison with that of a susceptible laboratory strain, as indicated by LD_{50}'s.

Compound	24-Hour LD_{50}'s, in γ/Female Fly, for Strains from				
	Laboratory	Hog Ranch		Dairy	
		A	B	A	B
DDT	0.033	>100	>100	>100	50
Methoxychlor	0.068	1.9	0.98	0.78	1.0
Lindane	0.010	0.27	0.45	0.27	0.080

synergistic effects against susceptible flies with combinations of DDT and piperonyl cyclonene, the effect depending on the dosage and ratio of components.

Exposure to Residual Deposits.—Data shown in table 7 give a comparison of the effects of residual deposits of DDT or methoxychlor (200 mg./ft.²) and of combinations of DDT or methoxychlor (200 mg./ft.²) with compounds 3, 9, 43a, and 43b (40 mg./ft.²) on susceptible and resistant flies, in terms of exposure period required for 50 per cent knockdown and for 50 per cent mortality in 24 hours. In general, the addition of the synergists increased the knockdown activity of DDT and methoxychlor to resistant flies to about the same level as that of DDT and methoxychlor alone to susceptible flies. The resistant flies, however, required two to six times as long an exposure to the residual deposits of the combinations for 50 per cent mortality in 24 hours as the susceptible flies required for the same mortality with DDT or methoxychlor alone. The relative effectiveness of the combinations is apparent, since a 3-hour exposure of resistant flies to DDT or methoxychlor alone caused no appreciable mortality in 24 hours, although 50 per cent of the flies were knocked down in this time.

Table 9.—Field trials with combinations of DDT or methoxychlor plus synergists (technical grade) 3, 9, 43a, and 43b.

Active Ingredients (Compound Plus Synergist) (Pounds per 100 Gallons Finished Spray)	Period of Control (Weeks)
Hog Ranch A	
DDT, 10 lb.+9, 8 lb.	2–3
DDT, 40 lb.+9, 8 lb.	4–6
DDT, 20 lb.+3, 4 lb.	5–6
DDT, 20 lb.+3, 8 lb.	6–8
DDT, 20 lb.+43b, 8 lb.	6–8
Hog Ranch B	
DDT, 20 lb.+9, 4 lb.	2–8[1]
DDT, 20 lb.+9, 8 lb.	4
DDT, 20 lb.+43a, 4 lb.	5–6
DDT, 20 lb.+43a, 6 lb.	5–6
Dairy A	
DDT, 20 lb.+3, 8 lb.	3–4
DDT, 20 lb.+43a, 4 lb.	2
Methoxychlor, 10 lb.+9, 2 lb.	2–3
Methoxychlor, 20 lb.+9, 4 lb.	2–4
Methoxychlor, 20 lb. (W.P.)+9, 4 lb.	2
Methoxychlor, 20 lb.+3, 4 lb.	2–4
Dairy B	
DDT, 20 lb.+43a, 8 lb.	4–5
Methoxychlor, 10 lb.+9, 2 lb.	3–4
Methoxychlor, 20 lb. (W.P.)+9, 4 lb.	5–6
Methoxychlor, 20 lb.+9, 12 lb.	3–4

[1] The longer period of control in this test was in a brood house, and the shorter period in the open.

Table 10.—Development of resistance in the laboratory to combinations of DDT and compound 9 by larval and adult selection of a resistant field strain (Bellflower 1951) with doses permitting 20 to 40 per cent survival of adults.

Generation	Larval Treatment, in p.p.m. Dry Weight of Media		Topical Treatment of Adults, in γ/Fly	
	DDT+Compound 9		DDT+Compound 9	
P_1			1.0	0.25
F_1	500	100	2.5	0.5
F_2	600	120	5.0	1.0
F_3	700	140	10	2.0
F_4	800	160	50	10
F_5	1000	200	100	20

Field Studies.—Limited quantities of technical compounds 3, 9, 43a, and 43b were obtained for field trials at two dairies and two small hog ranches near Riverside. The relative resistance of populations of house flies from these four locations is indicated by comparing their LD_{50}'s to DDT, methoxychlor, and lin-

Table 11.—Resistance of DDT-9-resistant strain (table 10) to combinations of DDT and compounds 3, 9, 43a, and 43b.[1]

Compounds	Topical Dose in γ/Female Fly	24-Hour Per Cent Mortality
DDT+9	100+20	50
DDT+3	100+20	89
DDT+43a	100+20	49
DDT+43b	100+20	32

[1] Before selection, topical doses of 100 γ of DDT alone/female fly caused 5 per cent mortality in 24 hours; combinations of 5γ of DDT and 1γ of compound 3, 9, 43a, or 43b/female fly caused 100 per cent mortality.

dane, with those of a susceptible laboratory strain, as shown in table 8. Combinations of DDT, methoxychlor, and the four synergists were normally formulated as xylene emulsion concentrates. A typical emulsion concentrate contained, for example: 10 pounds DDT, 2 pounds synergist, 1 pint *Triton X-100*, and xylene to make 5 gallons. In one case the methoxychlor was used as a 50 per cent wettable powder, and the synergist was added as an emulsion concentrate. The results of these field applications, in terms of weeks of satisfactory residual control, are given in table 9.

In general, the DDT-synergist applications gave as good control as, or better control than, any other materials which we have investigated since the development of resistance of the combined DDT-lindane type in southern California. Although the control obtained was generally better in the two hog ranches than in the two dairies, these results can be explained on the basis of differences in their structural make-up, and on the basis of the laboratory studies, which showed that the synergist combinations require a longer period of fly contact with the residues than DDT, when the latter is used alone with susceptible flies. The two hog ranches provided more treated surfaces on which the flies tended to rest, especially overnight, than did the relatively open milking barns of the dairies, where the fly population was more migrant.

Development of Resistance to DDT-Synergist Combinations in the Laboratory.—A logical consideration in the study of DDT-synergist combinations concerns the possible development of resistance to such combinations. Consequently, a series of experiments was undertaken, in which both larvae and adults of a resistant field strain (Bellflower 1951) were subjected to increasing doses of DDT and compound 9, in such concentrations that 20 to 40 per cent of the adults survived to maintain the strain. Larval mortality was not determined. The results of these treatments (Table 10) show that in five generations resistance had developed approximately to the level of that present for DDT alone before selection.

Results of tests with DDT and compounds 3, 43a, and 43b, against this DDT-9-resistant strain (table 11) show that high levels of resistance developed as well to these combinations. Although it is not possible to translate such results to the rate of development of resistance in the field, they presage the development of resistance if the use of such DDT-synergist combinations were to become extensive.

SUMMARY AND CONCLUSIONS.—1. Ninety-six compounds structurally related to DDT were examined as synergists for DDT against resistant house flies. Sixteen of these compounds showed a relative synergistic activity of 20 to 160 times, when compared with the activity of DDT alone as 1. None of the combinations was as active against resistant flies as DDT alone against susceptible flies.

2. Certain relationships of structure to toxicity were formulated.

3. Combinations of the three most active synergists, bis(*p*-chlorophenyl) chloromethane, 1,1-bis(*p*-chlorophenyl) ethane, and bis(*p*-chlorophenyl) ethynyl carbimol with DDT and methoxychlor, were studied in more detail in determining the following: (a) No optimum ratio of synergist to DDT or methoxychlor was found, activity increasing from the 1:100 to 10:1 levels. (b) Synergistic activity was evident when either DDT or a synergist was separately applied from 14 to 24 hours following the other. (c) A similar but smaller synergistic effect was found for methoxychlor than for DDT. (d) There was no indication of any synergistic effect for DDT against susceptible house flies. (e) The DDT- or methoxychlor-synergist combinations were about as effective in knockdown against resistant flies as was DDT or methoxychlor alone against susceptible flies, but resistant flies required two to six times as long an exposure to deposits of the combinations for 50 per cent mortality in 24 hours as susceptible flies required for the same mortality with similar deposits of DDT or methoxychlor alone. (f) Field applications of 20 pounds DDT and 4 to 8 pounds synergist per 100 gallons of finished spray have given satisfactory residual control of insecticide-resistant flies as long as 6 to 8 weeks in areas of heavy breeding, such as hog farms. Similar applications of DDT or methoxychlor and synergists in dairies were somewhat less effective. (g) Resistance to DDT-synergist combinations was rapidly developed in the laboratory to levels as high as those developed to DDT alone before selection.

4. Even though house-fly resistance to the best of these synergists was developed in the laboratory, the fact that such compounds are able to reactivate DDT to the extent of being practicable for residual applications in the field control of insecticide-resistant flies encourages further investigation for more active synergists and perhaps even for combinations against which resistance will not develop. Moreover, a more profitable field for study may be with specific synergists for methoxychlor or lindane, against which such high levels of resistance as for DDT, have not developed in the field.

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Ethylene Dibromide for Control of Black Hills Beetle

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Penetrating-oil solutions have been used for the control of certain bark beetles in the forests of western United States for many years. The development of such solutions reduced control costs and eliminated the hazards of burning infested material as a method of control. Salman (1938) reported the results of experiments with orthodichlorobenzene, paradichlorobenzene, crude flake naphthalene, and beta-naphthol dissolved in diesel oil to control several species of bark beetles in California. The infested trees were felled, limbed, and bucked, and the solution sprayed on the bark surface. Satisfactory mortality of the broods infesting Jeffrey, ponderosa, lodgepole, and sugar pine was obtained by the treatment when bark thickness did not exceed one-half inch. Gibson (1943) reported on the effectiveness of several oil solutions of fumigants on the mountain pine beetle infesting lodgepole and whitebark pine. He concluded that diesel oil-orthodichlorobenzene solutions combined low cost and control effectiveness to the greatest degree of any formula tested.

Since 1940 fuel-oil solutions of orthodichlorobenzene have been used extensively to control infestations of the Black Hills beetle. In 1947, in an effort to eliminate the costs of felling the trees before treating them, solutions of orthodichlorobenzene and fuel oil were applied to the bark of standing trees. The results were equal to those obtained in felled trees. Treating standing trees with a solution of 1 gallon of orthodichlorobenzene to 6 gallons of fuel oil has been the standard method of control since 1948.

Oil solutions of fumigants, while representing a tremendous advance over old methods of control, still had the disadvantage of being disagreeable to use and expensive. The cost not only included the purchase price of the oil at the tank car, but also its transportation into the forest by hand, pack animals, or jeeps. As a result of such disadvantages, tests were initiated in 1949 with water emulsions prepared from emulsifiable concentrates of various fumigants. Water is the most practical carrier of a toxicant where it can be used, because it is present in most forested areas.

During the summer of 1949 several hundred standing ponderosa pines in-

Table 1.—Survival of Black Hills beetle larvae in trees treated in the spring with emulsions of various fumigants.

Fumigant (Pounds per 5 Gallons of Emulsion)	Solvent	Per Cent of Water	Number of Living Insects per Square Foot of Bark
Ethylene dibromide:			
0	Fuel oil	60	23.0
1		60	1.1
2		60	.0
1		80	1.7
0	Cleaning	60	27.2
½	fluid	60	4.1
1		60	6.7
		70	1.5
		80	2.5
2	do	60	.8
		70	2.2
		80	.3
		90	.5
3	do	70	.3
		80	.1
		90	1.6
4		80	1.6
		90	2.3
0	Heavy	60	25.7
1	aromatic	60	4.0
2	naphtha	60	8.1
1		80	19.9
2		80	9.4
0	Cleaning fluid	60	31.3
1		60	11.1
2		60	7.6
1		80	11.8
2		80	5.8
Dichloroethyl ether:			
1	Cleaning fluid	80	29.5
2		80	32.9
4		80	18.4
8		80	20.4
Orthodichlorobenzene:			
2	Cleaning fluid	80	23.4
4		80	38.0
8		80	61.3
Orthonitrochlorobenzene:			
1	Cleaning fluid	80	37.9
2		80	30.1
4		80	40.0

[1] In cooperation with the Colorado A. & M. College.

fested with the Black Hills beetle were treated with emulsions of ethylene dibromide in various solvents. The solvents tested were fuel oil, red engine oil, ethyl alcohol, and a cleaning solvent. Triton X-155, an alkyl phenoxy polyethoxy ethanol, was used as an emulsifier. Ten trees were greated with each formulation. The brood stage at time of treatment varied from mature larvae to callow adults.

A tabulation of the results of these tests revealed that approximately 2 pounds of ethylene dibromide in 5 gallons of emulsion was the minimum satisfactory dosage. Both Stanisol and fuel oil proved effective as solvents of the ethylene dibromide. Approximately 10 per cent of the solvent was needed for effective control.

To improve the formulation further and to determine the effectiveness of other fumigants and solvents, more extensive tests were made in 1950.

MATERIALS AND METHODS—The fumigants, tested in emulsions and in solutions, included commercial grades of dichloroethyl ether, ethylene dibromide, nitrobenzine, orthodichlorobenzene, and orthonitrochlorobenzene. They were dissolved in No. 1 fuel oil, heavy aromatic naphtha (flash point 110° F.), cleaning fluid (flash point 121° F.), or cleaning fluid.

The emulsifiable concentrates were prepared by mixing the fumigant, solvent, and emulsifiers. They were clear solutions that were readily emulsified by water. In all cases each gallon of concentrate contained 8 ounces of a mixture of Triton X-100, an alkylated aryl polyether alcohol, and Triton B-1956, a modified phthalic glycerol alkyd resin. A blend of three parts of Triton X-100 and five parts of Triton B-1956 was used in the concentrates containing No. 1 fuel oil, but a blend of equal weights was used in the other concentrates.

The first series of applications were made during May against the larval stages, and the second series during the latter part of June and early July against the pupal and adult stages. The spring, or larval, treatments were applied by means of a tank-type pressure sprayer powered by carbon dioxide. Bucket pumps were used to apply the summer, or pupal and adult, sprays. A 6-foot extension rod equipped with a No. 6 solid-stream nozzle aided in reaching the upper part of the infested stems. Approximately 3 gallons of material was applied to each tree, the exact amount depending on its size. The trees ranged from 8 to 24 inches in d.b.h., and each was treated until the insecticide began to run from the bark surface.

Five infested trees were treated with each formulation to a height of approximately 20 feet, and at least 3 weeks elapsed before they were sampled for insect survival. These samples were taken at breast height ½-square foot in area on each of four sides of each tree. Only the live insects were counted. The mortality exhibited at this time determined the intensity of sampling needed in the treatment. If the mortality was sufficiently high to warrant further examination, the treated trees were felled and samples taken on opposite sides of each at heights of 1, 10, 15, and 18 feet. Untreated trees in the same area were sampled to determine the approximate mortality in the treated trees.

DESERT RESEARCH

At the International Symposium on Desert Research, held at Jerusalem, May 7 to 10 inclusive, 1952, and referred to in the February issue of this Journal, Professor F. S. Bodenheimer of Israel, spoke on "Problems of Desert Zoology and Desert Physiology" at the evening session on May 8. In all, thirty-four speakers covered such subjects as climate, biology, soil, and water and energy. Israel, the United States of America, France, the United Kingdom, Australia, India, Italy, and Algeria were all represented on the program.

Insects Associated with Papaya Virus Diseases in the Antilles and Florida

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Papaya (*Carica papaya* L.) is native to the American Tropics, its point of origin being as yet unknown. Facts tend to demonstrate that the southern part of Mexico is the original home of this fruit. Nowadays this plant is distributed throughout the tropical and semi-tropical areas of the World.

Botanically, *Carica papaya* L., is the type species of the Family Caricaceae, within the Order Passiflorales. According to Britton and Wilson, the family is composed of two genera: *Carica* and *Jacaratia*. *Carica* is native to the American Tropics and semi-tropics from Mexico to Paraguay, while *Jacaratia* occurs not only in America but also in Africa. According to Harms (1925) the Caricaceae is divided into four genera as follows:

1. *Carica*
2. *Mocinna*
3. *Jacaratia*
4. *Cylicomorpha*

The first three genera belong to tropical America, particularly Mexico, and *Cylicomorpha* has its original habitat in Africa.

Within the past few years papaya cultivation has made a great progress among farmers in the Antilles and Florida, because of the versatile character of the fruit. Papaya is not only a source of food but has many uses in industries and in medicine. Wolfe & Lynch (1950) discussed the uses of papaya in a recent publication.

Papayas are good sources of vitamins A, B, C, G. The fruit can be used for salads, pies, jams, and preserves. The green fruit yields a digestive enzyme: papain, which is a commerical product. The latex of the fruit is used as meat tenderizer and the pulp as an ingredient for cosmetic products.

The Agricultural Experiment Station of the University of Puerto Rico has been interested in papaya culture for many years. Studies with this crop were initiated about 20 years ago. More interest was taken when the virus diseases were first observed in the field and became limiting factors for papaya production in the island.

HISTORY OF PAPAYA VIRUS DISEASES IN THE ANTILLES.—The first report of a virus disease in papaya was made by the government microbiologist at Jamaica, Mr. F. E. V. Smith (1928–32). He reported as follows:

"Throughout the island, papaws are subject to a disease but this trouble is most noticeable on the Liguanea Plain. The plants are attacked at all ages, but more often the symptoms do not appear until the tree is about reaching the bearing stage. The terminal leaves as they emerge from the bud are yellow and frequently mottled while their size gradually becomes reduced until nothing but a pencil point is left. By the time this stage is reached the larger leaves hang down and gradual death is the result. Usually some adventitious buds lower on the stem start into growth, but the majority of these suffer the same fate, and strong growth is never regained. While root attack is suggested by the symptoms, it has not been possible to associate the symptoms with unhealthy root system and failure to find any organism in the tissues coupled with the mottling suggest that it is a virus disease. It has not been found that the disease is carried in the seed and other methods of transmission of a possible virus are being investigated."

Smith (1932) in 1930 mentioned once more that this disease had been a limiting factor to commercial papaya growing in Jamaica. In the same year, 1930, Ciferri (1930) discovered a mosaic disease of papaya in the Dominican Republic. A year later, 1931, Cook (1931) reported another virus disease of papaya in Puerto Rico, the first report of a virus disease of papaya recorded from the Island. Cook wrote as follows:

"What appears to be a virus disease of *Carica papaya* L. attacked the plants in the Station grounds a few years ago but the gardener destroyed the plants before the writer could make a study of them. This or a similar disease was later described by Dr. R. Ciferri of Santo Domingo as 'curly leaf' but he was uncertain as to the cause. My histological studies indicate that it is a virus disease. The young leaves become more or less curled

[1] Entomologist.
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and in severe cases this curling persists throughout the life of the plant. The lower leaves become yellow and fall. One or both symptoms may appear on the plants. Sometimes all the older leaves fall, leaving a cluster or rosette of leaves at the apex. In severe cases the fruits are reduced in number and size."

These reports were followed by additional information on the Jamaica virus published by Edwards (1933), Larter (1934–38), and Martyn (1933–38).

Reports by Stell (1937) followed by those of Baker (1936), concerned the presence of a papaya virus ravaging the papaya plantations of Trinidad.

In 1940, Acuña & Zayas (1940) described two papaya diseases in Cuba, both apparently caused by a virus. Reports on papaya diseases have been recorded from different parts of the World by many investigators, however, we shall discuss only the status of these diseases in the Antilles and Florida.

PAPAYA VIRUS DISEASE INVESTIGATIONS IN PUERTO RICO.—After Cook's first report on the presence of a virus disease of papaya in Puerto Rico during 1931 no immediate attempt was made to study the disease.

Jensen (1949) in 1937 and 1938, while working at the Puerto Rico Agricultural Experiment Station at Mayagüez, studied the "bunchy top" disease, described its symptoms, and made unsuccessful attempts to transmit the virus by mechanical means, budding and grafting. Tests to transmit the disease by means of the lacewing bug, *Corythucha gossypii* (L.), the stink bug, *Nezara viridula* (L.), the leafhoppers, *Agalliopsis pepino* (DeLong & Wolcott), and *Nesosteles incisa* (Matsumura) did not succeed. Jensen found a new species of leafhopper breeding on papaya, later named by Oman (1937) *Empoasca papayae*. Although Jensen worked with this leafhopper, his experiments were never completed and did not establish the relationship between the insect and the virus.

Alvarez (1941) initiated studies on the papaya virus diseases in 1940. He reported the following:

"Experiments were conducted in an attempt to transmit the disease mechanically and with the aid of possible insect vectors. The possibility of the disease being seed borne was considered. Several imported varieties of papayas were tested for resistance."

"During the last few years the papaya growing enterprise in Puerto Rico has suffered to a considerable extent due to the mosaic disease. This disease is considered a limiting factor in production. It has been impossible to determine the nature of the malady. All attempts to transmit the disease have been unsuccessful. Inoculated and check plants as well as trees grown from diseased fruit seeds remained symptomless while in the insectary. However, these plants became infected when taken to the field. The possibility of an insect vector is apparent. Wild papayas brought from Panama, Honduras, and Guatemala were found to be as susceptible as our varieties."

Simultaneously with these first investigations Cook & Asenjo (1941) were studying the chemistry of virus-infested papaya plants as well as the relations between the total content of protein and papain in papaya. For some reason these investigations were not continued until 1945, when the junior writer initiated a new project to study the virus diseases of papaya in Puerto Rico.

In 1945, Adsuar (1950) was working simultaneously with bunchy top and the papaya mosaic. He described the mosaic and verified its transmission by the green citrus aphid, *Aphis spiraecola* Patch. In 1946, Adsuar (1946–1950) found that *Empoasca papayae* was the insect vector responsible for the transmission of the bunchy top virus. In 1947, Sein (1947) confirmed this. At the same time the writers (Adsuar & Martorell 1950) were investigating the control of *Empoasca papayae* as well as of *Aphis spiraecola*. It was demonstrated that the *Empoasca papayae* is easily controlled by the application of Agricultural Grade DDT to papaya plantations every 15 or 20 days, starting with the first spraying on the papaya seedbed and continuing this spraying on schedule for the entire life of the trees. Experiments to control aphids responsible for the transmission of the mosaic by the use of modern insecticides including DDT, BHC and toxaphene gave negative results. During the autumn of 1947 and the winter of 1948, J. S. Caldwell & Martorell (1950) made a survey in Puerto Rico and nearby Islands to determine whether *Empoasca papayae* had a plant host other than pa-

paya. In 6 months of constant work collecting insects from the lowlands to the highlands it was concluded that *Empoasca papayae* has a single host plant: *Carica papaya*. Collections of *Empoasca papayae* were made once at lights in Río Piedras. In 1950, the junior writer made a preliminary study (1950) on the host range of papaya mosaic in which 49 species of plants representing 21 families were tested. Of these, the wild cucumber or "pepinito," *Melothria guadalupensis* was found susceptible to the papaya mosaic virus. *Melothria* proved to be a symptomless carrier and the virus could not be recovered after 2 months. In 1950 Bird and Adsuar (1952), also cooperated in these investigations, particularly on the bunchy top. Bird's investigations can be summarized as follows:

"Previous studies gave indications as to the viral nature of papaya bunchy top, but the evidence was inconclusive. Evidence obtained in present studies through the use of the leafhopper, *Empoasca papayae* Oman, associated with the transmission of the disease, was limited by the inability to secure non-viruliferous insect stock cultures. A single leafhopper was capable of transmitting the viral agent. After feeding on healthy plants for a period of one day the disease appeared one and a half months later. Evidence that the causal agent is capable of reproducing within the host plant was demonstrated by transmission of the causal agent in series through one plant after another by grafting. Latex failure to flow, as determined by pricking, shortly follows penetration of downward spread. Affected plants can be cured by cutting back the stem below the infected portion."

Because of discrepancies in the reports of different investigators, particularly in the Antillean area, it was very difficult to ascertain which disease or diseases of papaya were present in the Antillean Islands. The symptoms described were rather confused and sometimes those of more importance in describing the disease were not discussed. Because of this difference in opinion the writers began a series of trips throughout the Antillean region including Florida. It was the purpose of this investigation not only to determine the status of the existing virus diseases of papaya in the Caribbean Area, but to establish the relation of the possible insect vectors to the virus diseases under study.

STATUS OF THE VIRUS DISEASES OF PAPAYA AND THEIR INSECT VECTORS.—*Puerto Rico.*—Two virus diseases of papaya are known to occur in Puerto Rico. These will be referred to hereafter as: "bunchy top" and "papaya mosaic." Bunchy top virus is transmitted exclusively by the leafhopper *Empoasca papayae* Oman, while the papaya mosaic virus is transmitted by aphids or plant lice. The disease of papaya previously reported in literature (1946) as "die-back," is nothing but a form of bunchy top characterized by high virulence on susceptible papaya plants.

Bunchy top is the common papaya disease in Puerto Rico and is found everywhere in the island from the lowlands to the middle altitudes up to 2000 ft. high. Papaya mosaic is limited to a small area around the city of Ponce and the vicinity of Guánica. Why this disease is so limited in distribution is unknown. Both Ponce and Guánica are located on the south coast of Puerto Rico. The authors have never seen papaya mosaic in any areas other than the ones mentioned above.

Empoasca papayae Oman is the sole vector of bunchy top disease of papaya in Puerto Rico. The plant aphid, *Aphis spiraecola* is one of the proven vectors of papaya mosaic in the Island. In preliminary tests the junior writer has transmitted the papaya mosaic by the use of the aphis: *Carolinaia cyperi* Ainslie, *Myzus persicae* Sulzer and *Toxoptera aurantii* Fonscolombe.

Surveys made in Puerto Rico collecting insects on papaya since 1945 to date have demonstrated that *Empoasca papayae* Oman is the only leafhopper breeding on papaya in the Island. Not even by chance have any other leafhoppers been found breeding on this plant. During the spring of 1947 and the winter of 1948 the following insects (Caldwell and Martorell 1950) were collected from weeds and grasses growing under the shade of papaya plantations:

Cicadellidae:

Poeciloscarta laticeps Metcalf & Bruner
Hortensia similis (Walker)
Carneocephala sagittifera (Uhler)
Agallia albidula (Uhler)
Deltocephalus sonorus Ball
Deltocephalus flavicosta Stål
Deltocephalus maculellus Osborn

Sanctanus fasciatus (Osborn)
Graminella colonus (Uhler)
Chlorotettix tethys Van Duzee
Chlorotettix minimus Baker
Macrosteles divisus Uhler
Dikraneura delicata Osborn
Typhocybella minima Baker
Empoasca plebeia DeLong and Davidson

Fulgoridae:

Bothriocera undata (Fabricius)
Delphacodes propinqua (Fieber)
Delphacodes vaccina Caldwell
Melorminis antillarum (Kirkaldy)

It is interesting to note that, although breeding abundantly on the underbrush in papaya plantations, these insects were never collected on papaya foliage, not even while resting there. The only insects except *Empoasca papayae*, that have been collected on papaya foliage in Puerto Rico, though they were never found breeding on the papaya themselves, are: The leafhopper *Poeciloscarta laticeps* Metcalf and Bruner, and the fulgorids, *Oliarus complectus* Ball and *Omolicna puertana* Caldwell.[1] *O. puertana* is the most common fulgorid found on papaya in Puerto Rico. Whether it breeds there has never been verified.

In October 1946, Martorell & Francisco Seín visited Vieques Island and made a thorough survey of the insects affecting papaya there. During a 4-day survey only the leafhopper *Empoasca insularis* Oman was collected. No virus disease of papaya was found in Vieques Island. Papayas were perfectly healthy except for a serious outbreak of the disease known as *phytophtora* rot, which ravaged the papaya plants during that time.

Vieques Island was visited once more by Martorell and Caldwell and a thorough search was made from October 22 to 25, 1947. The only insects collected on papaya foliage at that time were: The fulgorids *Oliarus complectus* Ball and *Sanctanus fasciatus* Osborn and one male adult of the leafhopper, *Empoasca canavalia* DeLong, which was collected from a small plant in a papaya seedbed. At this time no virus disease of papaya was seen in this locality.

Virgin Islands.—During December 16 to 19, 1946, the writers visited the islands of St. Thomas and St. Croix and collected extensively throughout them. No virus disease of papaya was recorded during this survey. The only insects collected from papaya foliage in St. Thomas were the following:

Empoasca fabae (Harris)
Empoasca dilitara DeLong & Davidson
Empoasca sp.
Dikraneura sp.
Ormenis quadripunctata (Fabricius)
Aphis spiraecola Patch

Only one species of *Empoasca*, apparently a new one, was found breeding in the Island of St. Croix. The senior writer once more visited St. Thomas on June 1949, and later on during September 1951. The status of the papaya diseases in this Island remained the same: No virus disease of papaya was present.

Santo Domingo.—On September 1950, the senior writer visited the Dominican Republic, staying at San Pedro de Macorís through the kind hospitality of Mr. Jorge Serrallés. The writer had an opportunity to make a 3-day survey on papaya plantations around San Pedro de Macorís and vicinity. In Hacienda Las Cabullas, on the property of Mr. Serrallés, 60 per cent of the papaya plants in a 2 acre plantation were infested by bunchy top disease. Leafhoppers were breeding profusely on papaya trees and, after collection and identification, were found to be the common *Empoasca papayae* Oman. No mosaic disease was noted in the area at this time.

During November 1950 the writers once more visited the Dominican Republic and made a thorough survey around Ciudad Trujillo, Villa Duarte, Boca Chica, Haina, and San Cristobal. Leafhoppers were collected in all this area. Every single specimen was identified as *Empoasca papayae* Oman. The only disease present in this area was bunchy top showing exactly the same symptoms as the bunchy top found in Puerto Rico.

Haiti.—The trip was continued to Port-Au-Prince, Haiti. A survey was made around papaya plantations in the vicinity of Port-Au-Prince, Damien, Petionville, Tcholand, Leogane, Grand-Goave and Petit-Goave. The only insect found breeding on papaya during this survey was the leafhopper, *Empoasca papayae*. The only virus disease of papaya observed in Haiti, was bunchy top.

Cuba.—From Haiti the authors went to Camaguey, Cuba, on November 18, 1950. Around the Camaguey airport and in the city of Camaguey proper leafhoppers were collected from papayas and at the same time, the presence of the bunchy top disease was observed. The leafhoppers

were the common *Empoasca papayae.* Later in the afternoon the writers went to Havana, Cuba. On Monday, November 20 the Experimental Agronomic Station at Santiago de las Vegas was visited. During the trip a very large papaya plantation of around 30 acres was visited, (Hacienda Bijirita) and proved to be 100 per cent infested by the papaya mosaic. Leafhoppers, were collected there, while breeding abundantly on the papaya trees. They were identified as *Empoasca dilitara.* During this stay collections were made at Santiago de las Vegas, Bauta, Artemisa, Baracoa, Guanajay, and Porvenir. Except for Hacienda La Bijirita, where the papaya mosaic was very abundant, only the papaya bunchy top was observed. Leafhoppers collected at Baracoa and Bauta and the other localities mentioned above were identified as *Empoasca papayae.* These collections were made from bunchy top-diseased trees as well as from healthy trees near diseased ones. During October 1949 the senior writer had visited Cuba previously and collected leafhoppers from papaya at Guanabacoa near Havana. These were identified as *Empoasca papayae* and *Empoasca dilitara.* The insects were collected from apparently healthy trees. Bunchy top was noticed at Guanabacoa, but no leafhoppers were breeding on those trees at that time. No mosaic was observed in this area, although Guanabacoa is close to El Cotorro where the mosaic disease of papaya was reported for first time in Cuba. *Empoasca fabae* (Harris) had been reported by Bruner *et al.* (1945), and later by Acuña & Zayas (1939–40), as breeding on *Carica papaya* in Cuba. The authors did not find this species breeding on papaya in collections in Cuba. Although this is the most common species of leafhopper in Puerto Rico, and has been recorded from 15 or 20 host plants, it has not been found on papaya foliage in the Island during 6 years of constant search for papaya insects.

The work of Acuña & Zayas (1946) is among the best published in the Antilles regarding the papaya virus diseases. The authors knew very well indeed the difference between the papaya mosiac and our common bunchy top. They called the bunchy top, mosaic of the Type "A," and our common mosaic was identified by them under the name "Moasico del Cotorro," or Type "B" mosaic. The descriptions of the diseases in this work are very accurate and the present writers consider this publication as basic on papaya virus diseases. However, at that time the vectors of these diseases were not determined and Acuña & Zayas apparently were not sure of the identity of the vectors of these virus diseases.

Florida.—From Cuba the authors continued to Florida and between November 23 and 27, made a survey around Miami and vicinity, Homestead, Hollywood, West Palm Beach, and Vero Beach. Leafhoppers were collected from papaya trees in Miami University Campus, Miami, and Hollywood. These were identified as *Empoasca dilitara* DeLong and Davidson. Aphids were abundant on papaya throughout the area. Collections were made in the above-mentioned places and the aphids were identified as: *Aphis spiraecola* Patch, *Aphis gossypii* Glover and *Rhopalosiphum prunifoliae* (Fieber).

The only disease of papaya observed in Florida was the common papaya mosaic. No bunchy top was observed in the localities visited. Near West Palm Beach a leafhopper was collected from a tree showing symptoms like bunchy top, but not quite typical of the disease. The insect was identified as *Idona* sp.

Empoasca papayae has never been recorded from Florida. Poos & Wheeler (1943) have recorded *Empoasca plebeia* DeLong & Davidson[1] and *Empoasca dilitara* DeLong & Davidson from nymphs collected from papaya foliage in Florida. *Empoasca solana* DeLong and *Empoasca fabae* (Harris) were also recorded from papaya foliage, but the origin of the papaya plants is not mentioned by the authors.

Dr. John S. Caldwell, Circleville, Ohio, reported *Empoasca dilitara* from papaya growing spontaneously along the shores on Boca Chica Key, Vaca Key, and Grassy Key. All these collections were made in the Florida Keys during January and February, 1951. *Empoasca plebeia* was also collected on papaya at Vaca Key. No papaya mosaic was recorded by Dr. Caldwell while collecting throughout the Keys at that time.

Jamaica, B.W.I.—During December 1951, the senior author accompanied by Mr. Julio Bird, made a 3-day survey on

[1] For the original description of *Empoasca plebeia dilitara, fabae* and *solana* see DeLong & Davidson (1935), same, Harris (1841), and DeLong (1931), respectively.

Jamaica to investigate the status of the virus diseases of papaya in that territory. The southern coast of Jamaica from Port Royal, Kingston, Hope, Spanish Town, Indian Village, Old Harbor, Porus, and Mandeville was studied and collections of leafhopper were made at different places. This trip was made possible by the courtesy of Mr. Robert Buhrer, General Manager of Shell Co., West Indies Ltd. of Jamaica. We were accompanied by Mr. Michael Fawcus, in Charge of Agricultural Products of the Shell Co. Bunchy top was the only virus disease of papaya observed under study. All the leafhopper material collected at the different localities visited was identified by Dr. David Young of the U. S. National Museum, as *Empoasca papayae* Oman.

We noticed a scarcity of papaya trees on the area surveyed. No doubt bunchy top has considerably diminished papaya growing in this area of Jamaica. Only one winged aphid specimen was collected during our survey. This was at the Mandeville Hotel. The insect was identified as *Aphis spiraecola* Patch, by Miss Louise Russell of the U. S. National Museum.

CONCLUSIONS AND SUMMARY.—The bunchy top disease of papaya is found wherever its insect vecto, *Empoasca papayae*, occurs: Puerto Rico, Santo Domingo, Haiti, Jamaica and Cuba. The Virgin Islands (St. Thomas and St. Croix), Vieques, and Florida, are so far free from this disease.

The role of *Empoasca dilitara* as a vector of the bunchy top should be studied in Cuba, since it occurs there in combination with *E. papayae*. *E. dilitara* is common in Puerto Rico, but has never been collected from papaya.

Papaya mosaic is found in Puerto Rico, Cuba, and Florida. This disease is transmitted by various species of plant aphids. The symptoms of the disease are similar in all the areas studied, but whether the same virus occurs in all three places must be determined by further investigations. *Aphis spiraecola* Patch is a potent vector of the papaya mosaic in Puerto Rico. The role of the aphids found in papaya in Cuba and Florida should be further investigated.

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Continuous Vaporization of Insecticides with Special Reference to DDT

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Vaporization of insecticides by heat has been employed since insecticide-bearing materials such as ground pyrethrum flowers or tobacco juice were placed on fires or hot surfaces. Later, heaters were developed for the vaporization of such materials as naphthalene for control of greenhouse red spiders. Such methods were used intermittently and each treatment was of relatively short duration. One of the war-born devices for producing screening smokes for military purposes was adapted for civilian use and is now called the thermal aerosol fog generator. It is especially useful for space fogging open areas for the control of flying insects (Glasgow 1948). This process, too, is employed intermittently and makes the atmosphere lethal to insects for comparatively short periods of time. During World War II, English workers developed a technique for continuously dispersing bactericides by heat. Subsequently, DDT and certain other newer insecticides were found capable of continuous vaporization by heat. Beginning in 1947 investigations have been conducted at the University of Massachusetts on both fundamental and practical aspects of production and use of continuously vaporized insecticides. Toxicity studies regarding vaporized DDT were conducted at other laboratories.

VAPORIZATION RATES AND THEIR CONTROL.—Vaporizers are marketed for insect control in stores, theaters, restau-

rants and other enclosures. Within complete, or nearly complete, enclosures, air may be made lethal to a wide variety of arthropods by the constant and uniform vaporaiztion of desired amounts of insecticides. While it is possible to determine lethal concentrations of an insecticide for the various pests such values are of little use with field installations. Rates of air change within buildings vary greatly, being affected by such factors as type of construction, ventilation, numbers and size of doors and windows and outside weather conditions. In the absence of a practicable method for measuring concentrations of insecticides in air, commercial practice requires a rule of thumb for use in installing and operating vaporizers. The present accepted commercial practice is to use as a guide the limits of one gram per 25,000 cu. ft. per day and 1 gram per 15,000 cu. ft. per day. The first mentioned rate of use is satisfacotry under favorable circumstances while the figure of 1 gram per 15,000 cu. ft. is a recommendation of the Interdepartmental Committee on Pest Control (Haller & Simmons 1951). Operation within these limits requires a device that is constructed for long, trouble-free life, accurately controlled and capable of maintaining a constant rate of evaporation despite ambient or extreme room temperatures or drafs caused by fans, open doors or sindows.

Various machines for the continuous vaporization of insecticides have recently been made available in a wide price range. From a limited evaluation of the operation of such equipment, it seems that there is also a wide range in performance. Some heaters have been found to be without thermostatic controls so that room temperature, if high, increases the rate of evolution and low temperature or heat losses due to drafts decrease the rate of evaporation below the effective level. Others, having poorly constructed or controlled units, cause excess amounts to be evolved in the presence of drafts. In this case it appears that the thermostat employed is not suitable for this specialized use or is so situated that it is activated by temperatures which do not accurately reflect the heat of the insecticide. Most vaporizers do not permit suitable temperature measurement.

Obviously, safe and efficient operation of vaporizing instruments requires inspection to ascertain that performance is within the desired limits. Evaporation rates are directly affected by temperature and the surface area exposed. Knowledge of the temperature of the insecticide and the measurement of surface area should permit computation of the rate of evolution. Many insecticides, however, are subject to decomposition, especially when hot. Breakdown may be caused by the introduction of foreign substances, especially alkaline materials. Thus it is not desirable to insert a thermometer into the insecticide. Most crystalline insecticides tend to coalesce into a single "cake" preventing adequate contact between thermometer and chemical. In addition, the temperature of the insecticide, especially if in the crystalline state, varies with the distance from the heat source. Therefore, it seems preferable to insert a thermometer to a point in the unit where a consistent and characteristic temperature may be recorded and relate such a reading to a performance chart. These temperature records are of further use when it is necessary to regulate vaporizers for use in areas smaller than 15,000 cubic feet. For example, is a unit is to be installed in a 10,000 cubic foot room the thermostat could be adjusted to maintain a temperature at which between 0.4 gram and 0.6 gram would be evolved daily.

MEASUREMENT AND ADJUSTMENT OF TEMPERATURE.—The heating devices used in our experiments were supplied by the manufacturer,[1] who was first, in this country, to develop an apparatus for continuous vaporization. A detailed description of the *Aerovap* has been given by Underwiters' Laboratories, Incorporated (1950). The temperature of the unit is measured by inserting a thermometer into a special channel near the bottom of the vaporizer. This channel or thermometer well is so located that the bulb of a glass thermometer contacts both the center of the bottom of the insecticide cup and the surrounding heated casting at a point adjacent to the thermostat. The well temperature recorded at this point is higher than the temperature at the surface of the insecticide. Depending on the physical properties of the insecticide, the well temperature may exceed the surface tempera-

[1]American Aerovap, Inc., 170 W. 74th Street, New York City.

Table 1.—Vapor pressure of pp DDT (Balson 1947).

Temperature, °C.	10	20	30	60	100
Vapor pressure in mm. Hg	2.7×10^{-8}	1.5×10^{-7}	7.2×10^{-7}	5×10^{-5}	4.8×10^{-3}

ture by as much as 35° C. Although a relative figure, this well temperature can be correlated with rates of evaporation and is therefore useful in checking unit performance. Adjustment of the well temperature and consequent change in the insecticide vaporization rate are made by turning an adjustment screw at the bottom of the assembled unit. Thus, the operating temperature may be measured, and if necessary, adjusted quickly and conveniently without disturbing the insecticide or disassembling the unit. The production model of the *Aerovap* has a thermostatic adjustment from 100° to 150° C. (well temperature). Experimental units were provided that could be adjusted to any well temperature from room temperature to 250° C.

ADVANTAGES AND DISADVANTAGES OF VAPORIZATION.—In addition to its unique continuity of action over extended periods of time, vaporization of insecticides has certain advantages: (1) there need be no disruption of activities in the room being treated, (2) no diluent is used, eliminating the stains and odors common with spray applications and the dust deposits from dry applications, (3) the odor problem is negligible with proper choice and use of insecticides, (4) the process is economical in that extremely small quantities are used and there is no charge for diluents, emulsifiers or processing, (5) it is very ceonomical of labor. A vaporizing unit may be installed in 15 to 20 minutes and thereafter requires but an occasional inspection and replenishment of insecticide.

Likewise the process has certain disadvantages: (1) experience and skill are required on the part of the person locating the apparatus, (2) breakdown of insecticide due to accidental introduction of contaminants may result in loss of insecticidal activity and bad odors, (3) vaporizers are subject to defects which may occur with any mechanical equipment, (4) insecticides of high purity are required, (5) accurate control of rates of evaporation must be maintained under a variety of physical conditions. Such control necessitates the use of skillfully engineered vaporization devices and high quality thermostats.

VAPORIZATION OF DDT.—The vapor pressure for pure *para para* DDT given by Balson (1947) is shown in table 1.

It is apparent that air at room temperature can hold but little DDT in the vapor state and that any excess DDT must condense. When DDT is heated so as to evolve 1 gram per day from the *Aerovap* it is melted and maintains a liquid temperature of about 120° C. while the well temperature is approximately 130° C. (Fig. 1). DDT leaves the molten surface as a vapor but as soon as it reaches the cooler air, condensation to the liquid phase occurs and droplets are formed. This is analogous to the formation of water droplets when steam enters cool air. Stammers & Whitfield (1947) state that the aerosols produced when DDT is volatilized have a median particle size at the cup of 0.5 microns and at normal dispersal points in the room have an average particle size of between 0.5 and 5.0 microns. According to our observations DDT, when vaporized at what may be called a commercial rate (1 gram per 20,000 cubic feet per day) condenses into droplets, most of which are less than 12 microns in diameter. It is interesting to note that these droplets of DDT may remain in the liquid state at room temperature up to 4 or 5 days. They then crystallize into very fine needle-like crystals. Because of the very low vapor pressure of DDT these crystals remain for several months before subliming. An inhibitor of breakdown is required when DDT is subjected to heat for long periods of time as in vaporization.

DISTRIBUTION OF AEROSOL.—The insecticidal aerosol formed by the vaporization of DDT rapidly diffuses throughout the air in enclosures. Its existence may be determined visually by the Tyndall effect or by mortalities of suitably exposed test insects. In one series of tests the effect of the aerosol on houseflies at

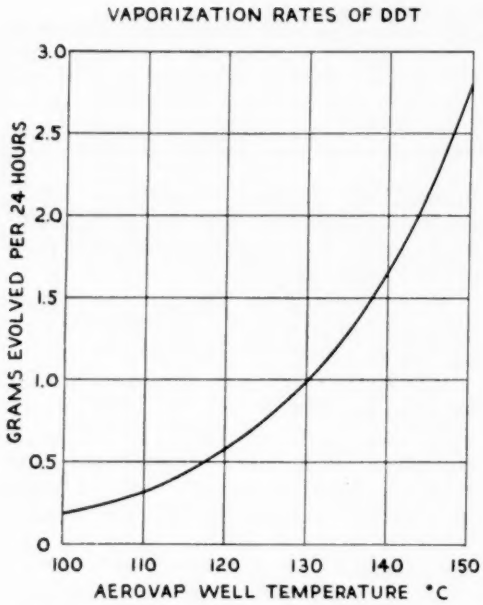

FIG. 1.—Smoothed curve of daily weight losses of DDT from 8 cm. cup in Aerovap at various well temperatures.

various locations in an enclosure was investigated in a rectangular room of approximately 3000 cubic feet. Flies in fabric cages (Spear 1951) were placed at eight positions chosen to sample the effect of the aerosol at various distances from the point of origin and heights above the floor. A vaporizer was operated until all flies were dead and mortality counts were taken at intervals. On the average, flies in cages placed on the floor died somewhat more rapidly than in elevated cages. On the basis of mortality in cages after 12 hours, flies in cages 80 inches above the floor showed slightly more effect than those at 33 inches, but on later counts this trend was reversed. These results suggest that initially the aerosol concentration is greater in the upper part of enclosed still air but after some period of time, the falling and condensing droplets tend to cause greater concentrations of insecticide in the lower part of the enclosure.

Tests were conducted to determine the effect of airborne insecticides alone by eliminating any influence of residues which the insect might reach. This was accomplished by suspending flies from threads. Nylon thread is best for this purpose as its tip can be fused in a flame to make a tiny ball. The ball is then coated with molten beeswax and quickly placed against the protergum of an anesthetized fly. The wax solidifies quickly without apparent damage to the fly. Such an arrangement permitted the flies to move their wings and legs without restriction. When not at rest, they flew in circles, but could not lift enough thread to touch any surface. With flies so prepared, those exposed to vaporized DDT were killed while those not exposed were unaffected.

In order to determine the areas of deposition of the DDT droplets from still air, glass plates were attached to the ceiling, walls and floor in a chamber resembling a Peet-Grady chamber. Approximately 0.5 gram of DDT was evolved into the 500 cubic foot room. In order to prevent air movement as much as possible all openings were tightly closed for the following 24 hours after which the plates were removed to an uncontaminated environment and exposed to houseflies for 24 hours. Of the flies confined over the plates from the floor 95 per cent died within 24 hours whereas none of the flies confined over the plates from the wall or ceiling died. Thus, it is apparent that all, or nearly all, the insecticide deposited as a residue from this aerosol system falls from still air onto horizontal surfaces. This finding agrees with those of Yeomans *et al.* (1949) who found that aerosols were deposited on horizontal surfaces from still air unless acted upon by a force greater than gravity. These workers found, however, that air currents generally exist to interfere with the downward movement of the particles. In contrast to these experimental conditions which were conducted in a room nearly hermetically sealed, in actual practice such completely still air is seldom, if ever, encountered. It seems likely therefore that only a small portion of the droplets from a continuously produced aerosol settle on horizontal surfaces under ordinary conditions of use. Their small size would be conducive to the particles being air-borne for long periods of time and to their being well distributed in the course of normal room ventilation.

APPLICATIONS.—The use of continuously vaporized insecticides is necessarily limited to more or less enclosed spaces. To date we have vaporized insecticides

on an experimental basis in homes, dormitories, stores, markets, a variety of poultry and animal shelters and other indoor areas. Most of the insect pests common to such areas are readily controlled by this method. In some cases where the flying form of the pest is involved, as in the case of houseflies or mosquitoes, control is achieved in a matter of hours. On the other hand, with such insects as silverfish, carpet beetles and clothes moths the method as presently employed appears more useful as a preventive measure or to achieve control after a longer period of time. For general use the vaporizers are operated continuously for long periods of time as a fly season in the northern part of the country or continuously in the south. However, they are adaptable to intermittent use.

Since vaporizers are sold primarily for fly control, there is little general use of DDT today because of housefly resistance to this insecticide. However, there are many pests, especially the smaller moths, flies and beetles which are pests of man's habitations or stored goods which can be readily controlled by vaporized DDT.

SUMMARY AND CONCLUSIONS.—Continuous vaporization of insecticides has been used to control certain insects in public and commercial buildings. Present insecticides should be evolved at a uniform rate per day between one gram per 15,000 cubic feet and one gram per 25,000 cubic feet. Sustained operation within these limits requires skilled design and location of dependable, accurate thermostats. Temperature control should be adjustable if units are to be placed in small rooms. A means of ascertaining operating temperatures is required other than insertion of a thermometer into the insecticide.

When properly applied vaporized insecticides are constantly effective without interference with normal routines and without appreciable odor, dust or stains. Labor and insecticides are economically employed. Vaporizers must be skillfully made, installed, and maintained. The insecticides must be pure, or very nearly so; breakdown may result in bad odors and loss of effectiveness.

DDT, having a very low vapor pressure, condenses into liquid droplets of aerosol size immediately after vaporization. The droplets remain liquid for several days and, being small, are dispersed by air currents. Distribution of the DDT was more or less uniform in a semi-commercial test. Insects are killed by the DDT suspended in air as well as by that which may be deposited on surfaces. Failure in control may be expected where resistant strains are encountered.

Vaporization is a useful method of insecticide dispersion in more or less enclosed areas. Many flying insects are quickly controlled while other flying forms and some crawling species are prevented from establishment or slowly controlled. In many cases eradication is obtained.

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Dictyospermum Scale in California

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A number of routine scale samples sent to this station from Ventura County in 1950 for determination of species proved to be dictyospermum scale, *Chrysomphalus dictyospermi* (Morg.). The occurrence of this scale in California, coupled with the request to determine whether it might be resistant to fumigation with hydrocyanic acid (HCN), led to the further investigation of its life history.

BRIEF REVIEW OF LITERATURE:— Dictyospermum scale, or Spanish red scale, as it is sometimes called, is one of the most important pest of citrus in the western Mediterranean Basin. In the eastern Mediterranean its importance as a pest of citrus is insignificant (Quayle 1941). Many of the early reports in the literature refer to it as "Morgan's scale." (Britton 1905, McDaniel 1931, Trimble 1925, Weiss 1916). The use of this name undoubtedly came about because it was first described by Albert C. F. Morgan in 1889, (Morgan 1889) from specimens taken from a palm, *Dictyospermum album*, at Demerara, British Guiana.

As early as 1905, dictyospermum scale was reported to be a serious pest of palms in commercial greenhouses in Connecticut (Britton 1905). Further reports indicate that it is distributed throughout the United States but is largely found only in greenhouses throughout the temperate zones.

The host list is long, some of the more common hosts being acacia, citrus, palms, latania, and rose. In Florida the scale can be found generally distributed on about 60 hosts in addition to citrus, but according to Watson and Berger, (1937) it is not a serious pest of citrus there. As the more common hosts of this scale (palms) are known to be natives of southwestern Asia, it may be concluded that the likely origin of this scale is in the same general region, or the near by Malayan region, as it is known that the genus *Chrysomphalus* is of Austro-Malayan origin as pointed out by McKenzie (1943).

Essig & Baker, in 1909, (1909) noted a report of the occurrence of dictyospermum in California on *Coelogyne cristate* Lindl., a free-flowering orchid. In 1913, a scale reported as a variety of dictyospermum (Whitney 1913) was taken on orchids growing in the conservatory in Golden Gate Park, San Francisco. The first definite record of an infestation of this scale in California was that reported by A. A. Brock (1915) in Ventura County in 1915. This infestation of scale occurred on Kentia palms in a greenhouse, and in order to eradicate the infestation, the palms were destroyed. The same year (1915) Essig received samples of dictyospermum scale from San Diego in the southern part of the state and from Marysville in the northern part (Essig 1916). The first infestation of the scale growing out of doors was found by H. J. Ryan on palms in Los Angeles (Chamberlin 1927).

Because infested shipments of avocados reached Santa Barbara in 1924, and a group of infested cocos palms arrived in Los Angeles in 1926, meetings held by representatives of citrus growers, over a period, resulted in the request for a survey to determine the importance of dictyospermum scale in California. A survey, principally of the avocado plantings in the state, was made in 1930. Results indicated that the major scale pest of avocados was the latania scale, *Aspidiotus lataniae* Sign., and not dictyospermum as was heretofore suspected. Dictyospermum scale proved to be third on the list of scale insects infesting avocados, and was found to occur mainly in Los Angeles and Orange counties in an area covering over 200 square miles (Mackie 1931). Since this survey, dictyospermum scale has been found on numerous hosts in the state, in nurseries, greenhouses, and citrus plantings.

In 1950 dictyospermum scale was found in nine different samples from Ventura County. Of these nine infestations, eight occurred in the Santa Paula area and one in the Ventura area. The scales were all taken from citrus, three of the samples being found on lemon fruits and the remaining six being found on citrus twigs, with no knowledge as to whether they were orange or lemon. This information would indicate that dictyospermum scale

Table 1.—Results of laboratory fumigation with HCN showing a comparison of per cent kill of non-resistant (NR) and resistant (R) California Red Scale and dictyospermum scale (Dict.) at different age levels.

Age of Scale in Days	Per Cent Dead Scale											
	1.0 Ml. HCN			2.0 Ml. HCN			3.0 Ml. HCN			4.0 Ml. HCN		
	NR[1]	R[2]	Dict.[3]	NR	R	Dict.	NR	R	Dict.	NR	R	Dict.
1–2	99.0	65.0	93.9	100.0	96.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
8–9	85.0	49.0	100.0	97.0	61.0	99.6	99.0	90.0	99.5	100.0	91.0	99.5
13–14	62.5	20.5	80.1	90.0	52.5	99.4	99.0	72.5	99.6	99.0	81.0	99.8
29–30	32.0	13.0	34.4	91.0	33.0	64.0	100.0	76.0	98.9	100.0	83.0	97.4
35–40	69.3	32.0	69.1	94.5	50.0	86.4	99.0	77.0	99.3	100.0	86.0	100.0
40–45	94.9	61.0	66.4	95.0	56.0	100.0	99.5	69.5	100.0	100.0	94.0	100.0
45–50	99.0	62.0	100.0	90.0	47.0	97.6	99.8	92.3	100.0	100.0	96.5	100.0

[1] NR—Nonresistant California Red Scale.
[2] R—Resistant California Red Scale.
[3] Dict.—Dictyospermum Scale.

possibly could become a pest in the citrus-growing districts of Ventura County if allowed to go unchecked. Quayle (1941) has stated that, on the basis of similarity of climate between parts of Spain and parts of southern California, he believes dictyospermum scale to be a potential pest of citrus in California.

LIFE HISTORY OF DICTYOSPERMUM SCALE IN SOUTHERN CALIFORNIA.—During the establishment of the culture of dictyospermum scale in the laboratory of the Division of Entomology at the Citrus Experiment Station, it was found that this scale does not develop as easily on banana squash as the California red scale. It was also noted that the young crawlers from the laboratory culture of dictyospermum scale could not be as easily brushed from previously infested fruit onto new grapefruit, as could California red scale crawlers. It was therefore necessary to transfer individual eggs and young crawlers to new grapefruit for fumigation tests. By this method a sufficient number of crawlers could be transferred to each fruit within a few minutes to obtain fruit bearing enough scale for test purposes. During the transfer of crawlers it was noted that there were no male scales present. In order to establish this fact definitely a few scale crawlers were transferred to two different grapefruits. As soon as it was established that the crawlers had settled, the halves of six No. 00 gelatin capsules were placed over individual settlers on each fruit and sealed to the fruit with wax. This provided 12 separate female scales, each within its own chamber and thus completely isolated from any male scales that might be present. The remaining young scales on the fruit were removed, and the encased settlers were allowed to develop to maturity at a temperature of 78° F. and at 86 per cent relative humidity. In time, each of the scales encased in half a capsule reached maturity and produced young scales. Some of these young scales succeeded in settling, and they, in turn, reached maturity and produced young. Thus it is established that the scales obtained from Ventura County reproduce parthenogenetically or without males.

Cressman (1933), in a discussion of the biology and control of dictyospermum scale, points out that there appear to be several different strains of this scale. This is indicated by reported differences in the reproductive habits: Moznette (1919) found that the dictyospermum scale in southern Florida appears to be parthenogenetic; but, according to Britton (1905), the scales that were observed in Connecticut were parthenogenetic and ovoviviparous, (bringing forth living young), and the males are unknown. Dictyospermum scales of the strain that Cressman worked with in New Orleans were oviparous, and fertilization was necessary for reproduction. Scales of the strain that was obtained from Ventura County for the present studies were found to be oviparous and parthenogenetic. Cressman (1933) observed that the eggs were deposited and hatched beneath the scale covering of the female; this was also the case with the strain of scales obtained from Ventura County.

In studying the life history of the dic-

tyospermum scales from Ventura, the eggs and crawlers and some adult females were transferred from lemons to grapefruits, as described above. The infested grapefruits were held at a temperature of 78° F., and at 86 per cent relative humidity, and the scales were observed daily in order to record their development. From these observations it was found that the time required for development of different stages averaged about as follows: from egg to crawler, one day; from crawler to whitecap, one day; from whitecap to nipple stage, one-half to one day; and from nipple stage to first molt, five days. This gave an average of eight days for the first instar. The time required between first and second molt averaged 13 days. From second molt to maturity averaged 15 days, and from maturity to presence of first eggs was another 8 days. Thus at 78° F., development from egg to egg again required, on the average, a little more than 44 days. This compares favorably with the 43 days required for completion of the life cycle, at 78.8° F., which Cressman obtained with the scale in New Orleans.

RESISTANCE TO HCN FUMIGATION:—In view of the fact that infestations of dictyospermum scale had been found in a number of localities in the Santa Paula area, there was some question as to whether the scale was resistant to HCN fumigation. At the request of the Ventura County Citrus Protective League, a series of resistance tests was conducted in the laboratory of the Division of Entomology at the Citrus Experiment Station. Dosages of 1, 2, 3, and 4 ml. HCN per 100 cubic feet were used, with exposure periods of 45 minutes.

Dictyospermum scales were fumigated along with both nonresistant and resistant red scales of the same age, to obtain a comparison and to determine the effects of HCN on scales of different ages. The scales were the same age in each group in the above-mentioned fumigations, with the age groups ranging from 1 to 55 days. In table 1 are presented the results of these fumigations.

In all fumigations the percentage of mortality of dictyospermum scale more closely followed the percentage of mortality of nonresistant red scale than of resistant red scale. For example: at dosage of 2 ml. HCN per 100 cubic feet, with scales 13 to 14 days old, the following mortality was obtained; nonresistant red scale, 90 per cent; resistant red scale, 52.5 per cent; and dictyospermum scale, 99.4 per cent. At a dosage of 4 ml. HCN per 100 cubic feet, with scales 29 to 30 days old, the percentage mortality of non resistant red scale was 100 per cent, that of resistant red scale was 83 per cent, and that of dictyospermum scale was 97.4 per cent. The dictyospermum scale from the Santa Paula area may therefore be considered nonresistant to HCN fumigation, when compared with nonresistant and resistant red scale under similar fumigation conditions.

SUMMARY.—Of forty nine scale samples sent in for routine determination from Ventura county during 1950, nine were identified as *Chrysomphalus dictyospermi* (Morg.).

Dictyospermum scales collected in the field were found to be oviparous and reproduced parthenogenetically. Cressman, who worked on dictyospermum in New Orleans, found the strain there to be oviparous, but that fertilization by males is necessary.

Life history studies conducted under laboratory conditions indicate that at 78° F. development of the scale from egg to egg required an average of 44 days.

Dictyospermum scale, which can be found in some commercial plantings of avocados, is a potential pest of citrus in California, especially in the coastal areas.

Results of laboratory fumigation tests with HCN, in which dictyospermum scale was compared with both nonresistant and resistant California red scale, indicated that dictyospermum scale is nonresistant to HCN fumigation.

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Corn Borer Development and Control on Canning Corn in Relation to Temperature Accumulation

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The development of the European corn borer, *Pyrausta nubilalis* (Hbn.), in the Midwest has been followed during recent years by plant examinations made either by the grower himself or by County, State, or Federal agencies which subsequently inform the growers of their findings. There has been an attempt to have observers make developmental checks throughout the season so that a complete picture of the borer might be obtained. However, in most cases where the farmer or canner was called on to follow such a program the results have been most disappointing. Corn growers are interested primarily in the occurrence and magnitude of egg mass deposition and early leaf feeding by the borer since it is on the basis of these factors that insecticidal control recommendations are based.

After working several years with sweet corn canners, it has been found that most cannery fieldmen are not able to schedule their activities in a manner that permits them to conduct a satisfactory insecticidal control program. The most frequent mistakes occur in the timeliness of egg mass counts and insecticidal application. To assist sweet corn canners in following corn borer development without their spending many hours in the field, an attempt has been made to establish temperature accumulations that would indicate the seasonal development of the corn borer.

Caffrey & Worthley (1927) recognized the possible use of temperature accumulations as an aid in forecasting the appearance of the various stages of the corn borer but from their experimentation with various climatic factors they concluded that temperature summation by itself was not satisfactory for practical purposes. These authors reported threshold temperatures of 44.3°, 36.5° and 41.2° F. for development of eggs, larvae and pupae, respectively. However, they stated that the straight-line thresholds, the temperature at which development becomes significant, for eggs, larvae and pupae were 58.7°, 49.7° and 55.4° F., respectively. Caffrey & Worthley indicated that the threshold temperatures would vary in accordance with humidity fluctuations or change in any of the other climatic factors.

In view of the fact that various stages of the corn borer have different threshold temperatures and that factors other than temperature have been found to have an effect on corn borer development, it is not surprising that investigators have been deterred from using temperature accumulations as an index of corn borer develop-

[1] Approved for publication by the Director of the Wisconsin Agricultural Experiment Station.

ment under field conditions.

Many Midwestern sweet corn canners are now using growing degree-day temperature accumulations to schedule the planting of corn and for an estimation of harvest date. A base temperature of 50° F. for corn was proposed by Barnard (1948), and the accumulation of the degrees above the base figure from the daily means constitutes the growing degree-days for corn.

A comparison of growing degree-day accumulations for corn with the appearance of the various stages of the corn borer for several successive years showed marked agreement and prompted the collection of additional data in support of this relationship. Borer degree-days differ from corn degree-days in that the former temperature accumulation starts with the first daily mean above 50° F. while in the case of corn the summation is not started until corn is planted.

Corn borer observations made during 1946, '47 and '48 in north-central Illinois[2] and during 1949, '50 and '51 in south-central Wisconsin were compared with temperature accumulations above base 50° F. obtained at Sycamore, Illinois and Madison, Wisconsin, respectively. The borer degree-days accumulated at the time the various stages of the corn borer were observed during the 6 years are shown in table 1 along with 6 year averages.

The standard deviations shown in table 1 indicate that two out of every three observations varied no more than 79 degree-days from the expected or average borer degree-day accumulation. Such a degree-day deviation is equivalent to three normal summer days in southern Wisconsin.

The average temperature accumulations shown in table 1 were made available to the investigators associated with the cooperative corn borer control program involving Iowa State College and the U. S. Bureau of Entomology and Plant Quarantine at Ames, Iowa. This group had assembled very complete data on corn borer development in central Iowa during the years 1949, '50 and '51, and they very graciously compared the average borer degree-day accumulations with their actual corn borer observations. From a temperature accumulation graph for each year they selected the date on which sufficient temperature had been accumulated to produce a given stage of the corn borer. The difference in days between these predicted dates of occurrence and the actual dates of occurrence are summarized in table 2.

Of the 23 comparisons in table 2, 17 or 74 per cent showed a deviation of 3 or fewer days from the expected date of occurrence. The most interesting feature of the Iowa data is that 48 per cent of the

Table 2.—Deviation in days of actual from predicted occurrence of corn borer phenological events in central Iowa.

Appearance of First	1949	1950	1951
Pupa		+4	+1
Moth	+3	−2	+2
First Generation			
Eggs	−1	+1	0
Hatching	−3	0	−1
Pupa	−2	−3	0
Moth	+1	+6	+8
Second Generation			
Eggs	−8	0	−1
Hatching	−6	+5	+1

[2] Records from Illinois were obtained by the author while employed by the Illinois Natural History Survey, Urbana. Certain of the Illinois data were provided through the courtesy of J. H. Paullus of the California Packing Corporation, Rochelle, Illinois.

Table 1.—Degree-day accumulation above base 50° F. for appearance of various stages of corn borer.

Appearance of First	North-Central Illinois			South-Central Wisconsin			Ave.	Standard Deviation
	1946	1947	1948	1949	1950	1951		
Pupa	243	252	258	238	256	230	246	± 11
Moth	446	409	423	388	450	—	423	± 26
First Generation								
Eggs	554	493	640	633	620	680	603	± 67
Hatch	649	579	736	730	742	759	699	± 70
Pupa	—	—	—	1400	1490	1448	1446	± 45
Moth	—	1625	—	1760	—	1764	1716	± 79
Second Generation								
Eggs	1724	1717	1827	1830	1780	1847	1787	± 57
Hatch	1849	1855	1969	1900	1885	1947	1901	± 49

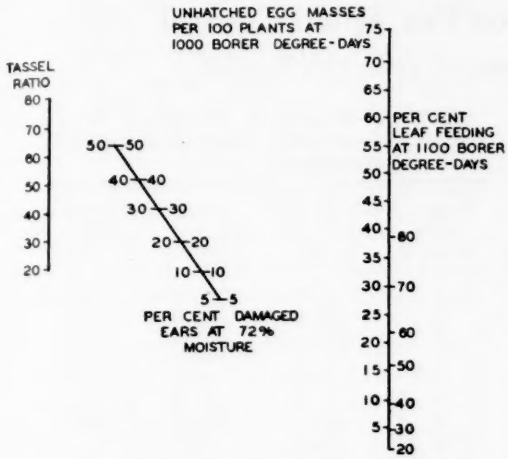

FIG. 1.—Alignment chart for estimating first generation corn borer damage to ears of canning type sweet corn.

actual observations varied no more than 1 day from the predicted. This application of borer degree-days was made for an abnormally early season (1949) as well as for two seasons that had above normal temperatures during the spring months but ended with normal (1951) or below normal temperatures (1950).

SCHEDULING CONTROL OPERATIONS.—By plotting the borer degree-day accumulation, a cannery fieldman is able to estimate the progressive development of the corn borer and as a consequence he is in a position to determine the best time to make egg counts and apply an insecticide in his specific locality. On canning type sweet corns where the corn borer population is not unusually high the greatest value from one or two insecticidal applications for first generation control can be obtained by treating late in the egg hatching period. In advance of the optimum treatment period, the canner must determine the need for treatment, and it has been suggested that this be done at 1000 borer degree-days which is equivalent to the time of 50 per cent egg hatching. Many corn growers choose to base the need for treatment on the proportion of plants showing leaf feeding. An evaluation of the infestation by this method should be done at the time of treatment or at 1100 borer degree-days.

In addition to determining the corn borer infestation, it is necessary to classify the maturity of the sweet corn before a decision can be made on the need for treatment. Wisconsin corn canners have been encouraged to use a maturity index called tassel ratio, Luckmann & Decker (1952), which is obtained on small plants by cutting the plant lengthwise and measuring the distance from the first node to the tip of the tassel and from the node to the tip of the longest leaf. The former measurement is divided by the latter and then multiplied by 100 to give the tassel ratio.

By use of the alignment chart shown in figure 1 an estimation can be made of the expected ear damage to canning sweet corn from a given first generation egg mass or leaf feeding count and plant maturity (Tassel Ratio). In Wisconsin, one insecticidal application is recommended at the time of 75 per cent egg hatching or 1100 borer degree-days, if 5 to 25 per cent ear damage is indicated. If the expected ear damage is more than 25 per cent, a second application is suggested at 1200 degree-days or about five days after the first.

SUMMARY.—A method for following the seasonal development of the European corn borer by the use of temperature accumulation is proposed. This accumulation, borer degree-days, is obtained by summing the degrees above 50 degrees Fahrenheit from the daily means. The borer degree-days for the appearance of various stages in the life cycle of the insect are given.

Temperature accumulations also can be used as a guide to indicate the proper time to make an evaluation of the corn borer infestation and time to make insecticidal applications. An alignment chart is presented by which a canning company can estimate the average amount of ear damage from first generation corn borer to be expected from a given egg mass or leaf feeding count on corn of known maturity.

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Further Experiments on Pea Aphid Control[1]

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The experiments herein reported were conducted (1) to determine the relative toxicity of several insecticidal dusts and low volume sprays on the pea aphid in the field, (2) to eliminate the mosaic disease by seed treatment and subsequent spraying, and (3) to determine the effect of the insecticidal sprays, dusts, and seed treatment on stand and yield of shelled peas.

A low volume spray boom was designed and used on experimental and commercial acreages.

Small Plot Experiments.—These tests were carried out on the experiment station farms near College Park. The Pride variety of wrinkled peas was used although it is not well adapted to this part of the state. It is more severely injured by mosaic than the less succulent, smooth-seeded varieties and was therefore selected for these tests. The peas were planted the first of April and harvested June 20. Plots were 5 by 120 feet and treatments were replicated 6 times in randomized blocks. All insecticides were applied on May 17 except treatments 1 and 2 (Table 1), and population estimates, based on 10 sweeps per plot, were made May 25, the approximate time of peak aphid populations in untreated plots.

Octamethyl pyrophosphoramide was applied to the seed in treatments 1 and 2, the latter plots receiving two subsequent sprays of DDT emulsion for the purpose of eliminating as nearly as possible the aphid infestation in hope of controlling mosaic disease. Attempts to determine accurately the percentage of mosaic-infested plants were not successful. Abnormal appearance and stunting were caused by local soil conditions and by direct aphid attack as well as by several strains of mosaic; the abnormalities caused by these factors could not always be accurately separated in the field. It was evident, however, from examinations and counts that considerable mosaic was present in plots of treatment 2. There was also evident a "check effect"—the highest number of abnormal plants occurring in check plots and those adjacent to the check plots.

Table 1.—Specifications of treatment applied in small plot tests.

Treatment Number	Nature of Treatments
1	Octamethyl pyrophosphoramide 8 ounces per bushel of seed.
2	Octamethyl pyrophosphoramide 8 ounces per bushel of seed, plus 2 applications of 30 per cent DDT emulsion, 1 pint per acre in 30 gallons of water.
3	1 per cent parathion dust, one application at 40 pounds per acre.
4	1 per cent DDT dust, one application at 40 pounds per acre.
5	50 per cent 4049[1] emulsion, 24 fl. oz. per acre in 30 gallons of water.
6	30 per cent DDT emulsion, 1 pint per acre in 30 gallons of water.
7	Untreated check.

[1] S-(1,2,-dicarbethoxyethyl) 0,0-dimethyl dithophosphate.

Table 2.—Results of treatments on plant stand, aphid population, and yield of shelled peas, small plot experiments.

Treatment Number	No. Plants per 30 Ft. of Row	Aphids per Sweep	Yield of Peas per Plot
1	132.6	35.0	28.4 lb.
2	139.1	23.0	28.0
3	176.0	111.3	28.6
4	184.8	252.0	29.0
5	179.6	36.6	33.8
6	179.3	92.8	28.6
7	184.1	682.5	25.3
L.S.D. 5%	24.4	24.1[1]	
L.S.D. 1%	33.0	32.9[1]	

[1] Based on treatments 1, 2, 3, 4, 5, and 6.

For seed treatments octamethyl pyrophosphoramide was used at the rate of one-half pound per bushel of seed and was diluted with enough water (350 ml.) to wet the seed thoroughly. The solution was poured over the seed in a tub and thoroughly mixed by hand. The treated seed was put in cloth bags and stored in an open shed to dry. These treatments were made two weeks before planting.

Results (Table 2) show that seed treatment with octamethyl pyrophosphoramide at the dosage used was highly effective against the pea aphid but caused a significant reduction (24 to 30 per cent)

[1] Scientific article No. A360, contribution No. 2341 of the University of Maryland Station, Department of Entomology.
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of stand. The dust treatments, parathion and DDT, were not as effective as the low volume sprays of DDT and 4049 in reducing aphid populations. Highest yields were secured with the 4049 emulsion low volume spray, but differences were not statistically significant.

Residue analyses made on several plots receiving the octamethyl pyrophosphoramide and the 4049 spray showed that pods at time of harvest contained 0.2 ppm of octamethyl pyrophosphoramide and shelled peas contained 0.1 ppm. No residue was detected on the 4049 sprayed peas.

LOW VOLUME SPRAYERS.—The development of highly toxic organic pea aphicides that are soluble and can be used in liquid emulsion form has made low volume spraying with small orifice nozzles a practical method of treatment. During the prewar period when ground derris root was the most efficient pea aphicide it was necessary to use comparatively large orifice high delivery nozzles to permit passage of suspended insecticide particles. Following the advent of DDT, Glasgow[1] did considerable work with low volume sprayers and his principles of boom design and dosage recommendations were followed with slight modification in the work here reported.

To secure consistent results with a high degree of effectiveness, thorough plant coverage is necessary. To obtain such coverage it is essential that all plants be sprayed from opposite sides. This is accomplished on a boom sprayer by arranging closely spaced nozzles so that they will apply the spray in two directions. The poorest boom design is the placement of nozzles in a single line all spraying downward; such booms have been often observed in commerical operation and many failures (with non-systemic poisons) have resulted.

The booms designed and used in this work have nozzles arranged in two rows, one directed 45 degrees to the right and the other 45 degrees to the left, all being directed downward at 45 degrees. From front to back, nozzles are placed so that the tips are opposite. This arrangement of nozzles is accomplished by boring and tapping two rows of holes 90 degrees apart in extra heavy 0.75 in. or 1-inch galvanized pipe; this provides for the 45 degree downward angle. These holes are then fitted with 45 degree street ells, one row directed to the right and one to the left; these in turn provide for the 45 degree forward and backward angles. The paired nozzles are 14 inches apart. Rather wide-angled hollow cone nozzles, 70 to 75 degrees, are used on this type of boom. The wide angle is desirable as it compensates to a considerable extent for the lifting and dipping of the ends of the boom on uneven ground.

Minimum dosage recommendations of Glasgow of 25 gallons of water spray per acre are followed. This is accomplished by using nozzles with an output of .16 gallons per minute at a vehicle speed of slightly over 5 miles per hour with 100 to 125 pounds pressure per square inch. In the field, speed and pressure are synchronized to give desired dosage.

In addition to the boom used on the experimental plots one was constructed by one of our canners. This boom was fitted to a sweet corn sprayer of the type described by Black. Results of this commercial operation with DDT emulsion spray, at the same concentration used in the small plot experiments, were quite satisfactory and the cost of treatment reduced considerably from that for high volume spraying. These lower costs result from less handling of water, more actural spraying time in relation to tank filling time, and a higher field speed with lighter equipment. Reduced equipment costs also result from adapting the spray unit to more than one crop.

SUMMARY.—Low volume water sprays of DDT and 4049 emulsion were superior to 1 per cent DDT and 1 per cent parathion dusts in these tests. At the dosages used, the 4049 spray was superior to DDT although control was at a satisfactory level with either substance. Seed treatment followed by two subsequent DDT emulsion sprays did not result in satisfactory control of pea mosaic disease in small plots. A low volume spray boom designed and described was highly satisfactory in experimental and commercial use.

[1] JOUR. ECON. ENT. 39: 195–9.

Methods for Determining Ethylene Chlorobromide and Ethylene Dibromide[1]

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In a previous paper (Sinclair & Crandall 1952), the authors described a method for the determination of ethylene dibromide in the liquid and gas phases by the use of monoethanolamine. It was shown that under the right experimental conditions monoethanolamine will react completely with ethylene dibromide in the liquid state and will absorb ethylene dibromide from the gas phase from a sample of air withdrawn from a fumatorium. These results were practical in that the total bromine content of an air sample from a fumatorium could be determined by chemical analysis and the ethylene dibromide equivalent calculated.

Because ethylene chlorobromide showed some promise as an efficient insecticide for the control of the oriental fruit fly, it was decided to determine (1) under what conditions ethylene chlorobromide would react completely with monoethanolamine in the liquid and gas phases, and (2) the conditions under which ethylene chlorobromide and ethylene dibromide could be determined when added in known amounts to citrus peel or pulp and subsequently hydrolyzed with monoethanolamine. These experimental data supplement other published results (Lindgren & Sinclair 1951) on the development of methods for determining organic halogens in the air in the fumigation chamber and as residues left in the product fumigated.

APPARATUS AND REAGENTS.—The hydrolysis of ethylene dibromide and ethylene chlorobromide with monoethanolamine requires heat to go to completion. The reaction was carried out in glass-stoppered Erlenmeyer flasks, the stoppers being clamped down to prevent their being blown out during the heating process (Fig. 1). For concentrated solutions, where not more than 3 ml. of monoethanolamine was used, 10-ml. flasks were satisfactory. For larger quantities, as when analyzing fruit samples, 250-ml. flasks were used.

The apparatus used in these experiments for aspirating the bromine is shown in figure 2. It consisted of two Erlenmeyer flasks (A, B) connected, in series, to three gas-washing bottles (C, E, F) having ground-glass stoppers containing outlets at the top and inlets which extended to the bottom and were attached to fritted cylinders to disperse the gas. On entering the system, the air was bubbled first through 20 per cent NaOH solution

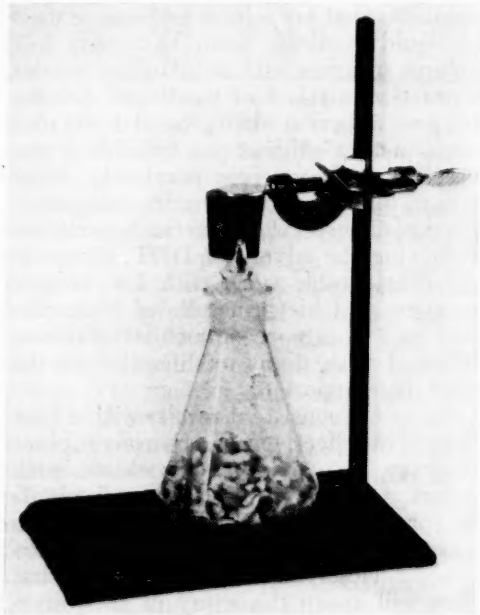

FIG. 1.—Reaction flask with stopper clamped down to prevent its being blown out during hydrolysis of ethylene chlorobromide with monoethanolamine in an oven at 100° C.

(A) and then through concentrated H_2SO_4 (B). Bottle C was the reaction chamber in which the bromine was liberated by the chromic acid reagent. A plug of glass wool was inserted in the exit tube (D) of the reaction bottle (C) to prevent the reagents from being carried over into the receiving flasks (E and F) during the period of aspiration. During a determination, the system was connected to a suction line or an aspirator pump, and air

PAID PAPER.

[1] Paper from University of California Citrus Experiment Station, Riverside, California.

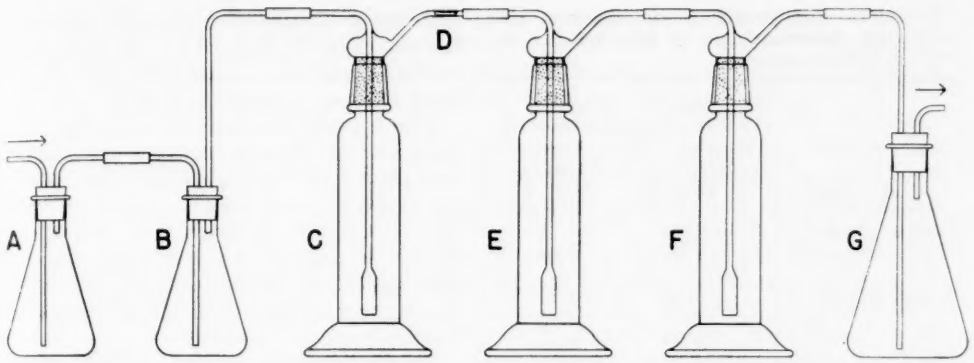

FIG. 2.—Apparatus used for aspirating bromine: flask A contains 20 per cent NaOH, flask B contains concentrated H_2SO_4, bottle C is the reaction chamber in which bromine is liberated by the chromic acid reagent, D is a plug of glass wool, bottles E and F contain 50 ml. each of 5 per cent KI solution, and G is a safety-trap flask.

was drawn through at the rate of 500 to 800 ml. per minute for 25 minutes.

The reagents used were the following:

(1) Sulphuric acid (stock solution) for transferring the ashed sample to the reaction chamber. Add 650 ml. concentrated H_2SO_4 to 1400 ml. water.

(2) Chromic acid solution for liberating bromine. Dissolve 200 grams chromic anhydride (CrO_3) in 1400 ml. water and add 600 ml. concentrated H_2SO_4.

(3) Potassium iodide solution to receive the liberated bromine. Dissolve 5 grams KI in 100 ml. water.

The colorimeter used was an A.C. model Fisher Electrophotometer. The absorption cells consisted of 23-ml. matched cylindrical glass tubes. The blue filter No. 425-B was found to be most satisfactory for reading the color intensities over the range encountered in these experiments. The makers of the instrument advice that, for maximum accuracy, readings should fall between the zero point and a reading of 50 on the "A," or intensity scale.

COLORIMETRIC METHOD.—To obtain data for drawing the standard calibration curve, a dilute solution of bromine in water was made, and varying amounts were added to 5 per cent KI solution in 100-ml. volumetric flasks. One milliliter of H_2SO_4 solution (1+4) was added to each flask, and the solutions were made up to volume. A portion of each solution was read in the colorimeter, and then the whole solution was titrated with standard $Na_2S_2O_3$ and calculated to equivalent bromine. From the two sets of data a curve was drawn, using bromine concentrations as abscissas and corresponding "scale-A" readings of the colorimeter as ordinates (Fig. 3). Colorimeter readings were made not less than 5 minutes nor more than 10 minutes after the H_2SO_4 was added to each solution. A small blank was obtained when reading pure KI solution with H_2SO_4 added against distilled water as a reference standard, and this was subtracted from each reading of the colored solutions.

For determination of bromine in fruit samples, the solution of iodine in KI from the receivers used in the CrO_3 method for bromine was transferred to a 100-ml. volumetric flask, 1 ml. of H_2SO_4 (1+4) was added, and the solution was made up to volume with distilled water. A portion was read in the colorimeter, and the reading, after subtracting the blank, was referred to the standard curve to obtain the corresponding bromine value.

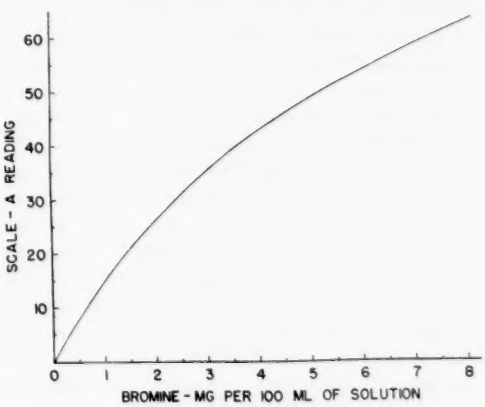

FIG. 3.—Calibration curve for bromine.

Table 1.—Comparison of colorimetric and volumetric determinations of bromine (as iodine) in various materials.

Material	Milligrams Iodine Determined by—	
	Colorimetric Method	Volumetric Method
Potassium bromide	1.62	1.51
	2.98	3.02
Methyl bromide	3.47	3.51
	3.45	3.47
	2.13	2.14
Ethylene dibromide	1.42	1.42
	1.52	1.50
	2.03	2.04
Ethylene chlorobromide	1.13	1.14
	1.10	1.11
	1.82	1.86
Mean	2.06	2.06

The degree of accuracy of the colorimetric values was ascertained by making volumetric determinations of bromine on the same solutions. The data in table 1 show the bromine determined as iodine by both the colorimetric and the volumetric method. The two sets of values show that these two methods give satisfactory agreement. The colorimetric method is better, however, for determining very small concentrations of bromine.

REACTION OF ETHYLENE CHLOROBROMIDE WITH MONOETHANOLAMINE.—Ethylene chlorobromide is completely hydrolyzed by concentrated monoethanolamine in 1 minute or less at or near the boiling point of the mixture. The reaction requires about 45 minutes at 100° C. The time routinely used was 1 hour at 100° C.

The method finally adopted for determination of ethylene chlorobromide was as follows: A known weight of ethylene chlorobromide was added to a 50-ml. volumetric flask containing 10 ml. of monoethanolamine. The flask, after it had been stoppered and the stopper wired in, was placed in a hot-air oven at 100° C. for 1 hour. It was then cooled, made up to volume with water, and 10-ml. portions were titrated by Volhard's method (Hillebrand & Lundell 1929) for halogens. In determining the KSCN value of the $AgNO_3$ solution, monoethanolamine should be added in an amount equal to that in the sample titrated, as it depresses the end point slightly. The factor for converting ethylene chlorobromide to its total halogen content is 0.8045.

The bromine content of the same solutions was also determined. A 3-ml. aliquot was placed in an evaporating dish, and 1 ml. of a 5 per cent water solution of KOH was added. The solution was evaporated to dryness and ashed in a muffle furnace at 500–550° C. for 30 minutes. Bromine was determined on the ash by a modification of Dudley's method (1939).

To the dry-ash residue, 25 ml. of the stock H_2SO_4 solution was added and transferred to a gas-washing bottle with a little water, using a rubber policeman to loosen the residue from the dish. A 25-ml. portion of the chromic acid solution was introduced, and the bottle was immediately connected to the receivers. At the end of the aeration, the KI solution in the receivers was transferred quantitatively to a 500-ml. Erlenmeyer flask, 1 ml. of H_2SO_4 (1+4) was added, and the liberated iodine was titrated with the standard thiosulphate solution (0.01 N), using 1 per cent soluble starch as indicator. The factor used to convert ethylene chlorobromide to equivalent bromine is 0.5572.

The values recorded in table 2 show

Table 2.—Recovery of etylene chlorobromide by different methods after hydrolysis with 10 milliliters monoethanolamine for 1 hour at 100° C.

Experiment	Ethylene Chlorobromide Used (Milligrams)	Ethylene Chlorobromide Recovered			
		Total Halides (Volhard Method)		Total Bromine (CrO_3 Method)	
		Milligrams	Per Cent	Milligrams	Per Cent
1	96.0	94.28	98.21	93.91	97.82
2	95.9	91.72	95.64	92.85	96.82
3	93.2	90.27	96.86	89.64	96.18
4	93.5	90.75	97.06	91.76	98.14
Mean	—	—	96.94	—	97.24

that ethylene chlorobromide reacts quantitatively with monoethanolamine under the conditions described above. The difference in recovery of ethylene chlorobromide obtained by the total halides (Volhard) and total bromine (CrO_3) methods is not statistically significant. In pure solutions either method can be used with equal accuracy for the determination of ethylene chlorobromide.

EFFECT OF DILUTION ON THE HYDROLYSIS OF ETHYLENE CHLOROBROMIDE

Table 3.—Effect of dilution of monoethanolamine (1 part by volume to 3 parts water) on hydrolysis of ethylene chlorobromide.[1]

	Ethylene Chlorobromide			
	Used		Recovered	
Experiment	Milligrams Weighed	Milligrams Calculated from Purity Factor	Milligrams	Per Cent
1	6.9	6.71	6.41	95.53
2	6.6	6.42	6.55	102.02
3	1.88	1.83	1.81	98.91
4	0.94	0.91	0.91	100.00
Mean	—	—	—	99.12
1	73.2	71.18	71.25	100.10
2	41.3	40.16	40.03	99.68
3	23.7	23.04	23.12	100.35
4	22.2	21.59	21.45	99.35
Mean	—	—	—	99.87

[1] Samples heated for 2 hours and 30 minutes in oven at 100° C.

BY MONOETHANOLAMINE.—Additional experiments were planned to determine the effect of dilution on the hydrolysis of ethylene chlorobromide by monoethanolamine, since this would be a factor in the determination of ethylene chlorobromide in fruit tissues. It was found that with increasing dilution a longer period of heating was required for completion of the reaction. From a practical standpoint, the difficulty of ashing arises when large amounts of monoethanolamine are added to fruit. In earlier experiments, the ratio of 1 part by volume of monoethanolamine to 3 parts of water was used, and the samples were placed in the oven for 2 hours and 30 minutes at 100° C. (Table 3). Later, the ratio finally adopted was 1 part of monoethanolamine to 2 parts of water, and the heating time in the oven was reduced to 2 hours. The analysis, following the heating period, was carried out as described above, and the ethylene chlorobromide was determined as bromine by the Dudley method (1939). The data of table 3 show the recovery of ethylene chlorobromide hydrolyzed with monoethanolamine in a ratio of 1 part of monoethanolamine to 3 parts of water. Determinations were made on samples ranging from 0.94 to 73.2 mg. The smaller and larger quantities taken for analysis were separated into two groups for purpose of comparison. The mean amounts of ethylene chlorobromide recovered in the smaller and larger groups were 99.12 and 99.87 per cent, respectively.

ABSORPTION OF ETHYLENE CHLOROBROMIDE FROM THE GAS PHASE BY MONOETHANOLAMINE.—The method used for the determination of ethylene chlorobromide in the gas phase was essentially the same as that already described for ethylene dibromide (Sinclair & Crandall 1952). Boiling flasks (1-liter capacity) having ground necks were fitted with inner joints carrying glass stopcocks. The ethylene chlorobromide was weighed in a small sealed ampule, which was placed in the dry flask, covered with a small glass plate, and crushed by tapping the plate with a glass rod (the glass plate prevents spattering of the ethylene chlorobromide onto the rod). The glass rod was immediately withdrawn and the flask closed by the adapter. The flask was heated slightly at the bottom to vaporize the ethylene chlorobromide; it was then cooled to produce a slight negative pressure, and 3 ml. of monoethanolamine was run in through the stopcock. The whole flask was warmed while being rotated to distribute the monoethanolamine, and was then placed in the oven at 100° C. for 1 hour. It was braced against the side of the oven to keep the adapter from being forced out during the heating period. The flask was cooled, the contents were rinsed out into a beaker, and the total halogens were titrated as before.

Results presented in table 4 show that, on the average, 100.56 per cent of the weight of the samples (corrected for impurities) was absorbed from the gas phase by monoethanolamine. It is evident that monoethanolamine can be used to hydrolyze ethylene chlorobromide in the liquid or gas phase. From a practical standpoint, these results are important in that samples of air containing ethylene chlorobromide can be withdrawn from a fumatorium, treated with monoethanolamine, and subsequently analyzed for total halogens or bromine, and finally calculated as ethylene chlorobromide.

RECOVERY OF ETHYLENE CHLOROBROMIDE AND ETHYLENE DIBROMIDE AFTER ADDITION TO ORANGE PEEL OR PULP.—It is important to know the conditions under which ethylene chlorobromide and

Table 4.—Recovery of ethylene chlorobromide from the gas phase by hydrolysis with monoethanolamine for 1 hour at 100° C.

	Ethylene Chlorobromide			
	Used		Recovered as Total Halides (Volhard Method)	
Experiment	Milligrams Weighed	Milligrams Calculated from Purity Factor	Milligrams	Per Cent
1	3.2	3.10	3.14	101.29
2	7.0	6.78	6.73	99.26
3	8.2	7.95	7.96	100.12
4	13.7	13.28	13.78	103.76
5	28.1	27.24	26.80	98.38
Mean	—	—	—	100.56

ethylene dibromide can be determined when added to citrus peel and pulp. Known amounts of these materials were therefore added to 50-gram samples of macerated peel and pulp contained in 250-ml. glass-stoppered Erlenmeyer flasks. Twenty milliliters of monoethanolamine was then added—an amount calculated to be approximately 50 per cent of the moisture content of the fruit sample. The flasks were stoppered and shaken to mix the contents thoroughly. After the stoppers had been clamped down to prevent their being blown out during the heating process, the flasks were placed in an air oven at 100° C. Heating periods for the ethylene dibromide and ethylene chlorobromide experiments were 1 hour and 2 hours, respectively. The flasks were then cooled and the contents transferred to porcelain evaporating dishes of 200-ml. capacity. Twenty milliliters of a 5 per cent aqueous solution of KOH was added to each dish, and the material was heated on asbestos mats over low flames to evaporate the water. The temperature was then increased slightly and heating was continued until most of the mass was charred. The temperature of the dishes should not rise above incipient redness; otherwise, some of the bromine may be volatilized.

The dishes were next heated in a muffle furnace at 500–550° C. until visible fumes ceased. During this process the mass puffs and may rise considerably above the edge of the dish. No loss is likely to occur, however, if care is used in removing the dish from the oven. When the dish was cooled to room temperature, water was added, and the charred mass was pressed down into the dish. It was again heated over a low flame to evaporate the water and returned to the furnace. By this procedure the inorganic salts were partially leached from the char, and the length of time necessary for ashing was materially shortened. Heating was continued until the mass no longer glowed when the furnace was opened. The dish was again removed and cooled. About 50 ml. of hot water was added. The mass was loosened from the dish with a glass rod, filtered through a rapid filter paper (12.5 cm. Whatman No. 41), and subsequently washed with a second portion of hot water. The paper with the residue was returned to the dish and again heated in the furnace until the residue was gray in appearance.

The dish was cooled at room temperature, and 3–5 ml. of 2N H_2SO_4 was added to dissolve the carbonates. The solution containing the dissolved ash was filtered as before and washed with two small portions of cold water, the filtrate and washings being received in the dish with the first filtrate. The combined filtrate was tested for alkalinity by removing a drop with a glass rod and adding a drop of phenolphthalein solution. If the filtrate was not strongly alkaline, a pellet or chip of solid KOH was added. The solution was then evaporated to dryness on a steam bath. Bromine was determined by the modified method of Dudley (1939), as described above.

The recoveries of known amounts of ethylene chlorobromide added to 50-gram samples of peel or pulp are noted in table 5. The conclusion drawn from these data is that monoethanolamine hydrolyzes ethylene chlorobromide in the presence of orange fruit tissues, and that ethylene chlorobromide can subsequently be determined as bromine.

Similar experiments were carried out with ethylene dibromide, except that the recovery values were determined by both colorimetric and volumetric methods (Table 6). The difference in recovery of ethylene dibromide by these two methods is not statistically significant.

SUMMARY.—Experimental conditions under which monoethanolamine will re-

Table 5.—Recovery of ethylene chlorobromide by the CrO_3 method after addition of known amounts of 50-gram samples of orange peel or pulp.

Experiment	Ethylene Chlorobromide			
	Added		Recovered	
	Milligrams Weighed	Milligrams Calculated	Milligrams	Per Cent
Peel				
1	5.80	5.64	5.64	100.00
2	1.57	1.53	1.58	103.27
3	1.57	1.53	1.52	99.35
4	1.57	1.53	1.55	101.31
5	2.32	2.26	2.29	101.33
6	2.32	2.26	2.28	100.88
Mean	—	—	—	101.02
Pulp				
1	1.16	1.13	1.10	97.34
2	1.16	1.13	1.15	101.77
3	1.16	1.13	1.13	100.00
4	1.87	1.82	1.80	98.90
5	1.87	1.82	1.78	97.80
6	1.87	1.82	1.83	100.55
Mean	—	—	—	99.39

Table 6.—Recovery of ethylene dibromide by colorimetric and volumetric methods after addition of known amounts to 50-gram samples of orange peel or pulp.

Experiment	Milligrams Added	Recovered by—			
		Colorimetric Method		Volumetric Method	
		Milligrams	Per Cent	Milligrams	Per Cent
Peel					
1	2.66	2.70	101.50	2.59	97.36
2	2.66	2.69	101.13	2.60	97.74
3	2.66	2.56	96.24	2.61	98.12
4	1.78	1.73	97.19	1.66	93.26
5	1.78	1.79	100.56	1.79	100.56
6	0.59	0.58	98.30	0.56	94.92
7	0.59	0.62	105.08	0.60	101.69
8	0.78	0.75	96.15	0.76	97.44
9	0.78	0.79	101.28	0.79	101.28
10	0.98	0.96	97.96	0.98	100.00
11	0.98	0.99	101.02	1.01	103.06
Mean	—	—	99.67	—	98.68
Pulp					
1	1.77	1.75	98.87	1.74	98.30
2	1.77	1.74	98.30	1.73	97.74
3	1.78	1.81	101.68	1.76	98.88
4	1.78	1.74	97.75	1.74	97.75
5	2.67	2.63	98.50	2.60	97.38
6	1.78	1.76	98.88	1.76	98.88
7	1.78	1.85	103.93	1.83	102.81
8	0.530	0.506	95.47	0.506	95.47
9	0.530	0.529	99.81	0.533	100.57
10	0.706	0.706	100.00	0.706	100.00
11	0.706	0.706	100.00	0.706	100.00
12	0.883	0.917	103.85	0.915	103.62
13	0.883	0.870	98.53	0.896	101.47
Mean	—	—	99.66	—	99.45

act quantitatively with ethylene chlorobromide in the liquid and gas phases have been determined. From the results of these reactions it is concluded that the total bromine or total halogen content of an air sample from a fumatorium can be determined by chemical analysis and the ethylene chlorobromide equivalent calculated.

Ethylene chlorobromide was quantitatively determined in the pure liquid and gas phases in terms of its total bromine or total halogen content. Either method may be used with equal accuracy for the determination of ethylene chlorobromide.

Methods have been developed for determining ethylene chlorobromide as bromine by both colorimetric and volumetric procedures.

Methods have also been developed for hydrolyzing ethylene chlorobromide and ethylene dibromide with monoethanolamine in the presence of orange peel or pulp and subsequently determining them as total bromine.

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SCIENTIFIC NOTES

Light Trap Studies on *Culicoides* in Puerto Rico

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Since World War II New Jersey type light traps have been run routinely by the military installations in Puerto Rico. Henry Barracks, which is located near the town proper of Cayey in the central mountainous regions of the Island is one such situation and here two light traps are kept in continuous nightly operation. Study of their collections over a period of almost three years has resulted in data on the relative abundance, flight range and seasonal variation of *Culicoides* which are presented below.

James (1943) introduced the use of light traps for systematic population studies on *Culicoides;* thereafter Fox & Kohler (1950) and Wirth (1951) also dealt with this subject. In the present survey collections from the two light traps at Henry Bks., P.R. were were studied from July 1, 1949 through April 30, 1952. Light Trap No. 1 ("Motor Pool Area") in 975 trap nights yielded a total of 963 specimens of *Culicoides* which were determined as follows: *C. inamollae* Fox & Hoffman, 900; *C. foxi* Ortiz (=*guttatus* Fox and Kohler), 29; *C. pusillus* Lutz, 29; *C. furens* (Poey), 4; *C. loughnani jamaicensis* Edwards, 1; Light trap No. 2 ("Civilian Housing Area") in 960 trap nights yielded 16,977 specimens which were determined as follows: *C. inamollae,* 16,837; *C. pusillus,* 80; *C. foxi,* 60. The two light traps were located at opposite ends of the camp on an east-west axis about one mile apart, yet one trap, No. 2, consistently yielded many more specimens of *C. inamollae* than the other, No. 1. These vast differences in numbers led to the supposition that trap No. 2 was located near good breeding places while No. 1 was not and that the flight range was in general less than a mile.

A seasonal variation of *Culicoidis inamollae* favoring late fall and winter was observed in the catch from both traps. This was more apparent in the yield from trap No. 2 where the specimens obtained were sufficiently numerous to be statistically significant and results were within limits consistent from year to year. The average number of specimens per trap night per month from trap No. 2 was calculated and the results are shown in Table 1. These data indicate that *C. inamollae* in central Puerto Rico is as a rule abundant from October through March and scarce from April through September and that peak months are usually November, December and February. It is reasonable to think that rainfall would explain the seasonal variation of *C. inamollae,* for there are usually heavy rains in Puerto Rico from September through December each year, but high precipitations also occur at other times. Unfortunately, the Weather Bureau did not have complete data on rainfall at Cayey except for the period July, 1949 through August, 1950. The available rainfall data could not be correlated with the results from the light trap, for example: the precipitation at Cayey in July, 1949 was 7.59 inches when the trap gave an average of one specimen per night while in February, 1950 the precipitation was 7.54 when the trap gave an average of 72.3 specimens; in August, 1949, the precipitation was 9.03 when the trap gave an average of 0.9 specimen while in November, 1949 the precipitation was 1.87 when the trap gave an average of 118.6 specimens.

Table 1.—Seasonal Variation of *Culicoides inamollae* as shown by a light trap at Henry Bks., P.R.

MONTH	NO. OF NIGHTS	AVERAGE PER TRAP NIGHT
July, 1949	29	1.0
August	28	0.9
September	28	3.1
October	35	50.9
November	28	118.6
December	34	18.3
January, 1950	28	27.1
February	28	72.3
March	25	30.6
April	35	10.4
May	28	2.5
June	28	0.4
July	35	1.1
August	28	1.9
September	14	0.3
October	13	0.2
November	23	11.5
December	25	100.9
January, 1951	27	2.0
February	27	1.9
March	34	0.8
April	27	0.6
May	27	0.2
June	35	1.5
July	28	0.1
August	27	4.4
September	35	8.3
October	28	27.0
November	27	40.6
December	35	2.1
January, 1952	28	1.0
February	33	21.2
March	27	18.2
April	25	1.2

For the most part the seasonal variation of *Culicoides inamollae* as demonstrated by light traps is in accord with that of *C. furens* as made known by other methods in other places. Hull *et al.* (1934) found greatest concentration of larvae in North Carolina mangrove marsh soil samples from January through March; Shields & Hull (1943) using emergence cages in Florida marshes found the highest peak from December through January; and Carpenter (1951) found a peak of abundance in horse baited traps in Panama during November and December. Even though these mutually confirmatory results are probably more than coincidental, it must be pointed out that a different species is here involved in a different ecological set-up. *C. furens* is a coastal species said to breed preeminently in brackish situations such as salt marshes, mangrove swamps and beaches and is oftentimes subject to tidal influences. *C. inamollae* breeds in pasturelands and sugar cane fields; in the case of Henry Barracks

such breeding places were in an interior, generally mountainous, region far removed from the sea.

The economic importance of *Culicoides inamollae* in Puerto Rico has yet to be investigated. It occurs abundantly around cattle and breeds in their pasturelands, hence it may feed on them. The name *inamollae* is in dispute, some authorities believe the species to be a variety of or even the same as *C. insignis* Lutz which was originally reared from coastal soil subject to tidal waves in Brazil and was known to attack man and cattle.

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A Community Project for Control of the American Dog Tick

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Accounts of successful experimental control of the American dog tick under strict, professional supervision have appeared in the literature a number of times but there have been few accounts of local community efforts toward tick control. For this reason, it seemed worthwhile to report on a tick control project which did not involve close professional supervision and one in which funds and manpower were supplied directly by the people of a community. The field work on this problem was accomplished in Jamestown, R. I., an island in Narrangansett Bay, about 8.5 miles long, and averaging between 1 and 1.5 miles in width. *Dermacentor variabilis*, although by no means as abundant here as in many other parts of Northeastern United States, was present in sufficient numbers so that local residents believed control measures desirable. The writer was requested to conduct a tick survey to determine the areas in need of spraying as well as to determine control efficiency after spraying was completed.[2] The pre-spray survey was conducted June 4 and 6, 1951; the spraying was effected on June 8, and the post-spray survey on June 12. Tick collections to determine density were made by three methods, which involved sampling of vegetation along roadsides at normal walking speed at 2.5 foot paces: (1) a sweep net 12 inches in diameter was swept back and forth at the rate of one sweep per step; (2) a 36 by 36-inch white flannel cloth drag, with a stick tacked to the front end to keep the cloth spread out, was drawn over the vegetation by means of a rope fastened to each end of the stick; and (3) collections from trouser legs were made at regular intervals during the sweeping and dragging operations. Ticks collected during the pre-spray survey were redistributed over the strip from where they were taken because in some instances the post-spray sampling covered part of the same strip area. Twelve stations were located along roadsides and paths which were sprayed because of frequent use by pedestrians. Eleven additional check stations were located in comparable areas which were not sprayed. Tick counts were made at all stations prior to spraying.

Table 1.—Average population of *Dermacentor variabilis* on Jamestown Island, Rhode Island, before and after spraying with 50 per cent DDT wettable powder at 4 lbs. per acre.

	NET (TICKS PER 100 SWEEPS)	TROUSERS (TICKS PER 100 PACES)	DRAG (TICKS PER 100 PACES)
Pre-spray (June 4, 6)			
12 stations in areas sprayed later (on June 8)	1.9	0.4	1.1
11 stations in area not sprayed	2.2	0.5	1.2
Post-spray (June 12)			
12 stations in area sprayed on June 8	0.0	0.02	0.04
11 check stations in area not sprayed	0.5	0.3	0.4

The operator was supplied with a map showing areas in need of spraying and given the usual instructions and precautions. A 50 per cent DDT wettable powder at 8 pounds to each hundred gallons of water was applied to a six to eight foot strip bordering several miles of roadside and paths at the rate of 4 pounds of actual DDT per acre.

A summary of results is given in table 1. According to all three types of samplings, the pre-spray tick population was but slightly greater in the check stations. Comparison of sprayed and unsprayed (check) areas following spraying revealed a 100 per cent control on the basis of sweeping net collections,

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[2] Assistance in this survey was received from John C. Kuschke and Frank R. Lisciotto of the Communicable Disease Center, U. S. Public Health Service, and J. A. Mathewson of the Rhode Island Department of Agriculture and Conservation.

95 per cent on the basis of trouser collections, and 90 per cent on the basis of flannel drag collections.

There was a noticeable natural reduction in tick collections in the check area between June 4 to 6 and June 12, measuring 77 per cent by sweep-net collections, 67 per cent by flannel drag collections, and 25 per cent by trouser collections. This same sudden early drop was apparent in other areas in the state but has never before been recorded so early in the season.

SUMMARY.—A community-sponsored program with prior professional advice but very limited professional supervision resulted in between 90 and 100 per cent control of *Dermacentor variabilis*. Control was accomplished by 50 per cent DDT wettable powder at 8 pounds to each 100 gallons of water applied to a 6 to 8 foot strip bordering several miles of roadside and paths, at the rate of 4 pounds of actual DDT per acre.

Life History and Control of Pecan Spittlebug in Illinois

S. C. CHANDLER

A spittlebug, *Clastoptera achatina* Germ., has become a serious pest of pecans in Illinois. It is present wherever pecans are found growing in the state. According to statements from nut growers and specialists from the U.S.D.A., it may be found almost everywhere in the United States within the range of its host.

In her paper "Host Records of Cercopidae in North America, North of Mexico," Dr. Kathleen Doering (1942) lists only two species of spittlebugs as feeding on pecan. These are *Clastoptera achatina* Germ. and *C. texana* Doering. All references in the economic literature for over 25 years refer to *C. obtusa* (Say) as the pecan spittlebug, but it seems quite possible that the early determinations may have been in error. Dr. Doering, who has identified the species reported herein as *C. achatina*, states in correspondence that *C. obtusa* is a hickory species and that the two species are readily and surely separable. In view of its economic importance, determinations in other pecan growing areas would be desirable.

The spittlebug appears to have two generations under Illinois conditions, with newly hatched nymphs appearing about June 1, and again about July 10. In cage studies adults of the second brood emerged throughout the entire month of August, reaching a peak about the middle of the month, and soon thereafter began to deposit eggs in small slits in the bark, several eggs to each slit.

In the orchard where studies were made at Anna, Illinois, in 1951, from 90 to 98 per cent of all terminals were infested by the time of the second brood. The type of injury most apparent seems to be the killing of shoots which would have produced fruit buds.

The results of preliminary spray tests indicate that this spittlebug can be readily controlled by spray applications containing 1 pound of 25 per cent lindane wettable powder per 100 gallons, with the trees sprayed to the point of run-off. Only fair control was obtained with parathion at the rate of 1.5 pounds of 15 per cent wettable powder per 100 gallons. Sprays containing TEPP at the rate of 0.33 pint of a 40 per cent concentrate per 100 gallons gave poor results.

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Injury to Peach Trees from Propylene Dichloride

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For the first time in 11 years of work with propylene dichloride emulsion for peach tree borer control in Georgia, injury to peach trees resulted from use of the recommended quantity.

Propylene dichloride and ethylene dichloride emulsions were used in experiments started in four orchards at Fort Valley, Georgia, in the fall of 1950. They were applied a few days after a rainfall of 2.37 inches. None of the trees treated with ethylene dichloride emulsion or the check trees showed any injury. However, of the trees treated with propylene dichloride, in two orchards from 2 to 6 were girdled with heavy injury into the cambium, in three orchards from 2 to 15 showed moderate injury into the cambium that extended one-half to three-quarters of the distance around the trunk, and in all four orchards from 2 to 18 showed light injury into the cambium.

It is our belief that the injury was due to the soil conditions that prevailed when the treatment was applied. Experience has shown that the danger of injury to peach trees from fumigant-type treatments, such as propylene dichloride, is increased when they are applied to water-logged soils. Low temperatures about a month after the applications may also have contributed to the injury from the propylene dichloride. A minimum temperature of 9° F. was reached on November 25, 1950. This is the lowest temperature ever recorded in November at Fort Valley, Georgia. Inasmuch as similar conditions could be encountered by peach growers at any time, the results reported herein appear to justify the withdrawal of recommendations of propylene dichloride emulsion for peach tree borer control. There is no justification for similar action with respect to ethylene dichloride emulsion.

Yearly Population Fluctuation of *Bombus morrisoni* at Fredonia, Arizona

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Bumble bees are valuable pollinators of various fruit and seed crops, but their usefulness is limited by their tendency to fluctuate strongly in abundance from year to year. This report concerns *Bombus morrisoni* Cresson,[1] one of the most important native

[1] Hymenoptera: Apidae.

pollinators of alfalfa in many intermountain localities.

Fredonia, Arizona, is a small community isolated by nearly five miles from the farms of the larger town of Kanab, Utah. Its few alfalfa seed farms are surrounded by semidesert range lands. Normally, the area supports enough wild flowers in April and May to meet the needs of overwintered queen bumble bees during their nest founding.

In 1948 and 1949 unusually large populations of *Bombus morrisoni* were present on the alfalfa seed fields during July and August. With favorable growing conditions and adequate insect control, the Thomas Jensen farm yielded approximately 840 pounds of clean seed per acre of the 40 acres left for second-crop seed in 1948. In 1949, the farmer reported a yield of 700 pounds per acre. The spring of 1950 was particularly dry and cold and farmers of the area reported that spring flowers were practically absent. Frost destroyed most of the early blooming garden flowers that might have provided some forage for the overwintered queens. Apparently as a result of these unfavorable spring conditions, bumble bees were rare in the Fredonia alfalfa seed fields during 1950. In June, before the alfalfa was in bloom, one queen and a few workers were seen near a barn. In July during peak bloom of the alfalfa no bumble bees were seen during an hour of observation. Honey bees were brought into Fredonia for the first time to aid in alfalfa pollination. Mr. Jensen had 30 colonies placed by the 60 acres that he left for second-crop seed, but his production of seed dropped to 180 pounds per acre. This concentration of colonies is generally considered insufficient for adequate pollination of alfalfa.

In 1951, the population of *Bombus morrisoni* increased markedly on the Jensen field but was still only about 10 per cent as large as in 1949. This time Mr. Jensen arranged for 50 colonies of honey bees to be placed on the 75 acres that he left for second-crop seed. His yield in 1951 was 400 pounds per acre.

On the Kanab fields, this bumble bee followed the same trends. However, populations were not so high during the two seasons prior to 1950, and in 1951 they more nearly approached the levels of 1948 and 1949. Sixteen miles to the east of Kanab, in Johnson Canyon, Utah, there was only a moderate decline in bumble bee populations in 1950. Yields in those two areas did not show a general decline in 1950. This may be explained by better control of injurious insects and the inauguration in 1950 of planned pollination with honey bees. Seed growers in the above mentioned areas have generally followed the insect control measures recommended by the State Experiment Station. In 1950 and 1951 Lygus bugs were held to a low level in most fields and there was no reason to suspect poisoning of bees since bloom stage applications were avoided.

At Fredonia, as in many other seed areas, it obviously would be wise to help the wild pollinators to survive adverse conditions. It seems likely that if a few acres of irrigated spring forage, such as vetch, had been provided for the bees in 1950, survival of queens and colony buildup would have been much better. It should be worthwhile for growers of any crop pollinated by bees to insure a succession of bloom in the area throughout the growing season.

A Method for Transferring Infestations of Purple Scale

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The infesting method described below has been used in California in the propagation of the purple scale *Lepidosaphes beckii* (Newm.). It is a method particularly suitable for scale insects that deposit most of their eggs before any hatch and whose newly hatched larva cannot be collected phototropically.

The most suitable insectary host plant for purple scale is the mature fruit of the citron melon (*Citrullus* sp.) particularly the dark green elongate variety, a medium first used for the culture of purple scale by the Agricultural Department of Orange County, California.

The melons are infested with purple scale by using the egg-filled scale covers. These are carefully scraped from infested host plants into small cloth bags (3 by 6 inches) made of material so closely woven that nothing larger than the newly hatched crawlers of purple scale can pass through it. For efficient transfer of the scale, egg-filled scale covers should be distributed uniformly throughout each bag when the bags are placed flat on the upper surface of the melons. The scale-containing bags remain in a "saddle" position on the melons for one or more days depending on the degree of infestation desired. The newly hatched scale move downward through the cloth and attach themselves to the host. The scales settle most readily at points where the cloth is in contact with the melon. When the surface of the melon beneath the basket is sufficiently infested, the melon is turned so that within four or five days the entire surface becomes infested.

The female contracts as it oviposits and few, if any, eggs hatch until oviposition is completed. The scale cover becomes completely filled with eggs in about ten days after the beginning of oviposition. In order to secure uniformity in scale development, the humidity should be 55 per cent or higher. The scales commence egg laying about 45 days after settling. Each scale produces 60 to 80 eggs. At 80°F the hatching of the full complement of eggs is completed in about ten days.

Uniformity of scale development is desirable from the standpoint of obtaining eggs for infesting and in utilizing the scale for parasite culture. It permits a rapid turnover of material, with consequent decrease in amount of equipment and in the chances of contamination with pests such as red mites, predatory mites, and mealybugs.

Other methods of transferring coccid infestations such as brushing, blowing, the use of temporary hosts, and phototropic and geotropic manipulation have been described in previous publications (Flanders 1949, 1951; Smith & Armitage, 1931).

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Toxicity of Organic Insecticides to the Fall Armyworm

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During the fall of 1951 the Mississippi Delta area experienced one of the heaviest infestations of the fall armyworm, *Laphygma frugiperda* (A. & S.), known in recent years. Serious damage was done to young oats, wheat, and permanent pastures. In localized areas this insect also did serious damage to cotton from early to midseason and in several places control measures were required.

For many years the standard control of fall armyworms was by the use of poison baits. With the appearance of the organic insecticides the search for more efficient and effective methods was started. Brooks & Anderson (1947) found a dust mixture containing 3 per cent of DDT, 5 per cent of chlordane, and sufficient BHC to give 1 per cent of gamma effective when used against this pest on corn. Kulash (1948), using applications of 10 pounds per acre, found that a dust containing 5 per cent of DDT plus sufficient BHC to give 3 per cent of gamma gave greater and quicker kill of armyworms than either 20 per cent toxaphene or 5 per cent chlordane. Blanchard & Chamberlin (1948) discovered that oil solutions and emulsions of DDT, BHC, chlordane, and TDE applied to corn ears gave very effective control. Hofmaster & Greenwood (1949), investigating the control of the fall armyworm on truck and forage crops, found that DDT dusts and sprays were, for the most part, effective in southeastern Virginia. TDE sprays and dusts also gave 98 to 100 per cent control of young armyworms feeding in pastures. Parathion and toxaphene also showed promise for the control of the fall armyworm.

In 1951 infestations that averaged 22.8 fall armyworms per square foot afforded an excellent opportunity to test some of the new organic insecticides in the form of emulsion sprays. Tests comparing 16 treatments were conducted on a field of volunteer oats near Stoneville, Mississippi. The oats, heavily intermingled with grasses, ranged up to 6 inches in height. Fall armyworms were actively feeding on both the grasses and oats at the time of treatment.

Plots 40 inches wide and approximately 30 feet long were laid out for treatment. To avoid possible contamination by drift untreated areas of 40 inches wide separated the treated plots.

Insecticides were mixed on October 11 at 10:30 A.M., and all plots were treated between 1 and 2:30 P.M. on the same day. During the 24 hours following treatment, the temperature ranged from 38° to 77° F., and the relative humidity from 30 to 100 per cent. There was very little wind movement during the application, and therefore practically no drifting.

Applications were made by hand with a knapsack sprayer, using a 1G nozzle, at the rate of 3 gallons per acre. A line pressure of approximately 40 pounds per square inch was maintained.

Records on mortality were made 24 hours after treatment. On four 1-square-foot areas taken at random from each treated plot the living and dead larvae were counted. All inactive larvae were recorded as dead. Records were not made after 48 hours, as larvae were observed moving from the untreated to the treated plots and would have made any records taken of little value.

Table 1.—Effect of several organic insecticides applied as sprays on the fall armyworm.

Insecticide	Pounds of Toxicant Per Acre	Number of Larvae		Per Cent Mortality After 24 Hours
		Alive	Dead	
Aldrin	0.25	14	48	77
BHC	.4[1]	15	63	81
Chlordane	1.0	33	49	60
Compound 269[2]	.1	40	41	51
	.2	10	111	92
Compound 711[3]	.1	46	2	4
	.2	47	45	49
DDT	.5	14	56	80
Dieldrin	.15	23	122	84
EPN	.3	10	58	85
Heptachlor	.5	19	60	76
Parathion	.2	80	61	43
TDE	.5	10	39	80
TEPP	.1	118	0	0
	.2	78	37	33
Toxaphene	2.0	9	102	92

[1] Gamma isomer.
[2] A stereoisomer of dieldrin.
[3] A stereoisomer of aldrin.

The results of these tests are shown in table 1.

The larval mortality ranged from 0 to 92 per cent. In 9 of the 16 treatments it was more than 75 per cent. Outstanding among the materials were compound 269 at 0.2 pound and toxaphene at 2 pounds per acre, both of which gave 92 per cent kill. Dieldrin was the only insecticide used below 0.2 pound per acre which gave over 50 per cent kill. TEPP was the least effective material used.

Of the larvae collected at the time of observation 51 per cent were in the third instar and 38 per cent in the fourth instar.

As yet little is known about the residues following the use of some of these insecticides on food crops for human and animal consumption. Extreme care should always be used in handling organic insecticides and recommendations of local agricultural leaders should be followed.

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[1] Acknowledgment is made to E. W. Dunnam, under whose general direction this study was carried out, and to M. V. Courtney for his able assistance.

Trials with Lime in Controlling DDT Residues on Forage at Harvest

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Numerous workers have shown that alkaline materials can cause a dehydrochlorination of DDT and other chlorinated hydrocarbon insecticides even under normal conditions. It appeared possible that the inclusion of an alkaline material in DDT formulations might accelerate degradation of residues in the field so that applications made closer to harvest than normal could be reduced to safe levels without seriously affecting the immediate insecticidal action. A variation in the proportion of alkali might even permit some control of the rapidity of the degradation, to fit the desired period of effectiveness and the expected interval before harvest.

The possibility was tested on forage crops, the feeding of which to dairy cattle makes harvest residues particularly undesirable. Lime was chosen as the alkaline material, both because of its ready availability and known safety to plants and because any lime getting into the soil would be of benefit to the New York soils which tend to be acid and deficient in calcium. Roth (1947[2]), showed that high calcium limes mixed with DDT degraded the latter almost completely in two weeks when the mixture was stored in bulk at laboratory temperatures. The effectiveness of lime on residues would be less because of its rather rapid reaction with atmospheric carbon dioxide (Wilcoxon & McCallan 1938) to form calcium carbonate which is inactive toward DDT. Since the rate of this carbonation appears to vary widely with the formulation, the seriousness of this limitation can be determined only by trial. The tests on mixtures of DDT and lime were carried out in 1949 and 1950.

MATERIALS AND METHODS.—The lime used in all experiments was the brand shown by Roth (1948) to give the most rapid reaction with DDT among those tested. It was combined with pyrophyllite and DDT to give a series of dusts each containing 5% of DDT and the following percentages of the other components:

Lime (*per cent*)	*Pyrophyllite* (*per cent*)
0	95
10	85
25	70
50	45
75	20
95	0

Technical DDT was used in the 1949 experiments and both technical and aerosol grade in analogous formulations in 1950 because of the frequently reported difference in reaction rates caused by the associated compounds in the technical product. The 10 per cent lime concentration was also omitted in 1950. Each dust was mixed in a small blender and hammer mill and applied on the same day.

In 1949 the experiments were laid out in a field of alfalfa-brome grass mixture in a randomized block design. The plots were 9 by 50 feet and replicated 3 times. In 1950 the experiments were laid out in the same field as in 1949. The plots were 10 by 20 feet and replicated 3 times in randomized blocks. A forage, even-feed power duster was used to apply the insecticides in 1949 while a hand fertilizer spreader was used in the smaller plots of 1950.

Insect counts were taken from net sweepings from the plots 2, 4 and 14 days after application.

Hay samples were taken periodically for analysis of the residues. The samples consisted of 1 square foot of standing hay per plot or 3 square feet per treatment. The samples were weighed immediately, stripped with benzene, and were analyzed by the colorimetric method of Schechter *et al.* (1945).

RESULTS AND CONCLUSIONS. Summarized and presented in table 1 are the results of the analysis of samples taken from certain lime-DDT plots.

Table 1.—P.p.m. of DDT in hay samples from plots treated with lime-DDT formulations. Minetto (Oswego Co.) N. Y.

DAYS OF WEATHERING	0% LIME, 95% PYRAX	25% LIME, 70% PYRAX	50% LIME, 45% PYRAX	75% LIME, 20% PYRAX	95% LIME, 0% PYRAX
DDT in p.p.m. (green weight) Lime plus Technical DDT					
0	348	176	283	176	190
7	8.0	11.2	7.0	9.7	7.1
14	6.0	8.3	3.6	3.1	3.6
Per cent loss in 14 Days	98.3	95.3	98.8	98.3	98.2
Lime plus Aerosol DDT					
0	217	239	197	207	171
7	27.1	18.7	16.4	14.0	13.8
14	19.6	16.2	15.0	8.3	9.8
Per cent loss in 14 Days	91.0	93.3	92.3	96.0	95.0

Table 1 shows that the use of high calcium lime with either technical or aerosol DDT did not appreciably reduce the residue after 2 weeks over those formulations where no lime was used. The freshly mixed DDT-lime formulations may have caused a speedier loss of DDT in the first few days after application, but in 2 weeks the residues from the DDT formulations where no lime was used were not greater than where lime made up 50 per cent or less of the formulation and was not significantly greater than where lime constituted 50 per cent or more of the formulation.

It is believed that under field conditions the calcium hydroxide carbonates too rapidly to undergo extensive reaction with DDT. Wilcoxon & McCallan (1938) in studying the weathering of bordeaux mixture showed that the carbonation of lime was 95 per cent complete in 3 hours. Therefore it is probable that where heavy dews or rain affect the deposits of dusts the rate of reaction is comparable, and the lime loses its power to dehydrochlorinate the DDT in the field before the desired reduction in residue can occur.

The control of the insect complex of alfalfa is summarized and presented in table 2. The counts were made from 20 net sweepings for each treatment.

[1] The authors are indebted to the Geigy Co. Inc., of New York whose financial support made this work possible.

[2] Roth, Roger W.—Thesis, Cornell University, 1947.

Table 2.—Summary of insect counts, showing the average control of the insects of alfalfa following treatments with lime-DDT dusts. Minetto (Oswego Co.) New York.

	0% LIME, 95% PYRAX	25% LIME, 70% PYRAX	50% LIME, 45% PYRAX	75% LIME, 20% PYRAX	95% LIME, 0% PYRAX	CHECK
48 hour count						
Grasshoppers	75	66	44	53	48	195
Lygus bugs	10	9	8	7	6	13
Pea Aphid	8	8	7	6	7	40
Spittlebug	3	3	4	5	1	7
Clover leafhopper	6	2	4	3	3	16
Potato leafhopper	1	1	1	1	1	4
Hypera and *Sitona spp.*	0	3	1	3	2	2
Total	103	92	79	78	68	277
Per cent reduction insect complex	62.9	66.8	71.1	71.9	75.5	
96 hour count						
Grasshoppers	56	65	49	50	43	174
Lygus bugs	13	8	8	14	12	9
Pea Aphid	1	2	5	3	1	21
Spittlebug	1	2	1	2	1	5
Clover leafhopper	2	1	2	0	2	7
Potato leafhopper	2	1	2	1	1	4
Hypera and *Sitona spp.*	1	1	0	1	0	2
Total	76	80	67	71	60	222
Per cent reduction insect complex	65.8	64.0	69.9	68.6	73.0	—
2 week count						
Grasshoppers	188	156	219	160	166	219
Lygus bugs	12	5	7	14	5	5
Pea Aphid	1	9	10	5	10	27
Spittlebug	5	5	7	9	5	9
Clover leafhopper	5	4	5	5	8	14
Potato leafhopper	2	3	2	4	3	2
Hypera and *Sitona spp.*	2	3	5	4	4	7
Total	215	185	255	201	201	283
Per cent reduction insect complex	24.1	34.6	10.7	29.0	29.0	—

Control of the insect complex was not outstanding, due probably to large numbers of grasshoppers that are difficult to kill with DDT. Lygus bugs, spittlebug adults, and pea aphids which are readily controlled by DDT, were not found in numbers large enough to influence the total insect complex control. The use of lime in the formulation did not affect the toxicity of the DDT nor hinder its residual action in controlling the insect complex. This was in agreement with the results of the residue determinations.

SUMMARY.—A series of experiments were conducted during 1949 and 1950 to determine if high calcium spray lime could be used in various proportions in DDT dusts to control the residue of DDT at harvest. Both technical and aerosol DDT were compared.

While lime increased the rate of DDT loss for the first few days after application, the residue after 2 weeks was the same whether or not lime was used in the DDT formulations. It is believed that under field conditions, the fresh lime carbonated in a few days and no longer was chemically active with DDT. There was no significant difference between the persistence of technical and purified DDT residues.

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A Nectarometer

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To collect and measure nectar from both floral and extrafloral nectaries in cotton, a gadget called a nectarometer has been devised (Fig. 1). A microburette stopper is attached to a glass tube having an inside diameter of 3 mm., calibrated in 0.1 ml., with a total capacity of 1.0 ml. Above the calibrated portion the tube is enlarged and divided. To one division is attached a rubber tube for mouth suction. To the other, by means of a sleeve of rubber tubing, is attached a 2-inch capillary tube. The overall length of the apparatus is 190 mm. (about 8 inches), and the graduated portion of the tube 85 mm.

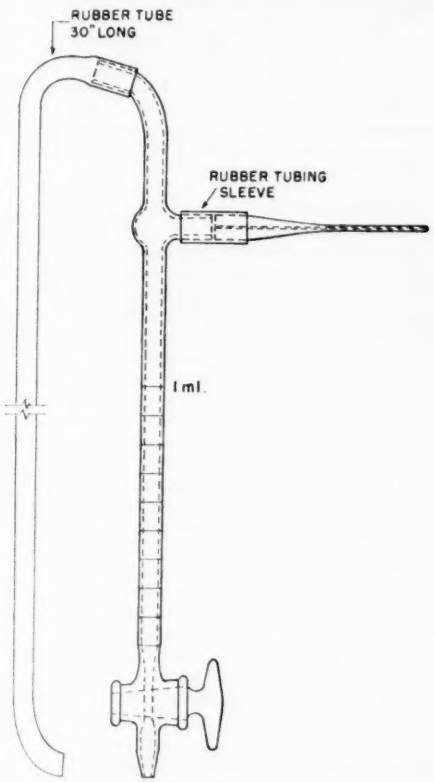

FIG. 1.—Nectarometer, showing capillary tip for collecting the nectar, suction tube for pulling the nectar into the burette for measurement, and the stop-cock for removing the nectar and for cleaning.

To collect nectar the capillary tube touches the nectar which moves up the tube by capillary action. Suction from the mouth tube then pulls the nectar into the enlargement at the "T" from which it flows down into the calibrated portion. When nectar from the desired number of nectaries has been obtained, direct quantitative reading is made. Although the nectarometer does not relieve the nectary of all the nectar, it is conservatively estimated that as much as 90 per cent of the nectar is obtained which is considered satisfactory for comparative purposes. The method is rapid in that one ml. can be collected within a few minutes from about 25 cotton flowers.

Residual Effect of Chlordane on Crabgrass when Applied to Lawn for Control of Sod Webworm[1]

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During 1949 a sod webworm, *Crambus* sp., was very abundant on lawns in Central Wisconsin. A DDT spray (1.5 lbs. of 50 per cent W.P. in 25 gals. of water) was used on July 24 with excellent control resulting. The larvae came to the surface and died within a few days. On the same day, a strip was sprayed with chlordane emulsion at approximately 10 lbs. actual per acre to test the effectiveness of chlordane against the webworm. This insectcide also effectively controlled the insect. Neither insecticide appeared to affect the grass adversely, *i.e.*, there was no browning of grass as a result of the spraying.

In midsummer of 1950, observations of the plots sprayed in 1949 showed that the strip sprayed with chlordane was much greener than the area sprayed with DDT. Examination revealed that the difference was due to the absence of crabgrass in the chlordane treated strip. This same strip continued to remain practically free of crabgrass during the 1951 season.

During 1951 a series of three Latin squares involving six different treatments representing the components[2] of the emulsion used in 1949, a chlordane wettable powder and checks were established to determine whether the chlordane itself or some other ingredient or combination in the emulsion caused the disappearance of the crabgrass. To test the effect of time of application, treatments were made June 21, July 20 and August 13.

Periodic examinations throughout the remainder of the season showed no essential differences between check and treated plots and it was concluded that the effect observed had to be on either the seed or the very young plant.

Very recently B. H. Grigsby reported inhibition of crabgrass germination by chlordane in greenhouse tests. He stated that "further trials over a longer period of time are needed to determine whether chlordane will inhibit crabgrass germination in treated sod."

With the time of effect established and a different carrier used by Grigsby showing that it is actually chlordane which is responsible, the purpose of this note is to record the fact that treatment with chlordane emulsion at 10 lbs. actual per acre will inhibit the development of crabgrass in lawns for at least two seasons following application to lawns on Plainfield sand in Wisconsin.

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[1] Approved for publication by the Director of the Wisconsin Agricultural Experiment Station.

[2] Supplied through the courtesy of the Riverdale Chemical Co., Harvey, Illinois.

Metaldehyde Dusts for Control of Slugs Affecting Brussels Sprouts in Central California

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The gray garden slug, *Deroceras reticulatum* (Muller),[2] and the green-house slug, *Milax gagates* (Draparnaud), are often severe pests of certain vegetables in the central coastal areas of California. Poison baits containing metaldehyde and calcium arsenate (Lange & MacLeod 1941) have given effective control under most conditions. During the past several years, however, growers of Brussels sprouts often have found it necessary to bait six or more times during the growing of a single crop at an expense of approximately $40.00 an acre. Inasmuch as it is the usual practice to dust every 10 days with a parathion dust for cabbage aphid control, the feasibility of adding a contact or repellent chemical to the parathion, or using a contact poison alone, seemed worthy of investigation.

The use of baits in the case of Brussels sprout production has not proved too effective for several reasons; first, the plants reach several feet in height; second, there are numerous places for refuge under the large leaves which are dropped to the ground by the pickers as the crop is harvested; and third, the slugs often remain in the centers of the plants during the day and do not reach the ground.

The literature contains numerous references to contact molluscacides. In addition, a number of materials have been tested by the senior author during the period 1936 to 40. These earlier experiments demonstrated the value of a dust containing 20 per cent monohydrated copper sulfate and 80 per cent hydrated lime. Dusts with hydrated lime alone, cupric oxide, and nicotine were also found to be of some value, but were effective for only short periods. Experiments as early as 1940 showed that a 10 per cent metaldehyde dust was effective in killing eggs of *Deroceras reticulatum*, and in killing adults by contact.

Metaldehyde, a polymerized acetaldehyde, is primarily used in slug and snail baits as the attractant in combination with a more active poison such as calcium arsenate. At the usual concentrations in baits (1.5 to 3 per cent) it is most effective in exposed situations where the stupified mollusks succumb to dessication following their exposure to sunlight. In cool weather, or in protected situations' metaldehyde does not seem to be an active enough poison to give high mortalities when used alone in baits. Tests have shown that higher concentrations of metaldehyde in baits are actually repellent to certain mollusks. In addition, the incorporation of higher concentrations of metaldehyde in bait combinations with arsenicals may actually limit the acceptance of baits as mollusks are affected before they can ingest toxic quantities of baits. Chemical analyses of both slugs and snails indicate that as the metaldehyde content of metaldehyde-arsenical baits increases from 1 to 5 per cent by weight the ingestion of arsenic expressed as arsenic trioxide decreases by about one-half.

Certain of these observations seem applicable to the use of metaldehyde in dust form. Metaldehyde dusts applied directly to slugs causes immediate distress and the exudation of copious quantities of slime. The slugs often become extended and the genital organs are often extruded. In cases where the slugs can get out of the dusts and are not exposed to dessicatory influences, they often can slough off the dust and survive. On the other hand, in situations where the slugs are exposed to sunlight, most of them succumb to the metaldehyde dusts. The dosage, amount applied, and whether the slugs are dusted directly or crawl through the metaldehyde are also important considerations.

Table 1.—Effect of metaldehyde dusts on slugs in cage experiments.

Per Cent Metaldehyde in Dusts	Per Cent Mortality at Day Intervals Following Exposure[1]				
	1	2	3	4	5
Direct Application to slugs					
1.0	0.0	0.0	15.0	20.0	20.0
2.0	0.0	17.5	37.5	42.5	72.5
5.0	0.0	60.0	100.0	—	—
Check	0.0	0.0	0.0	0.0	0.5
Application to leaves on which slugs are placed					
1.0	0.0	0.0	0.0	10.0	75.0
2.0	0.0	35.0	55.0	60.0	100.0
5.0	0.0	35.0	35.0	45.0	100.0
Check	0.0	0.0	0.0	0.0	0.0

[1] Mortalities at each time interval refer to per cent dead in relation to total number of slugs caged.

Tests during 1951 at Half Moon Bay were conducted in small cages so that a more careful evaluation of the amount of metaldehyde required in dusts could be determined. Dusts containing 1, 2, and 5 per cent metaldehyde were dusted directly upon adults of *Deroceras reticulatum* and *Milax gagates*, and, in addition, leaves of Brussels sprouts were dusted and the mollusks placed upon them. Ten slugs of each species were dusted, and a similar number allowed to crawl through the deposits, and each test was replicated two times. The screen cages were placed in the field between rows of Brussels sprouts, and the slugs were protected from direct sunlight. The slugs were examined daily and mortality recorded. Leaves of Brussels sprouts served as food. The dusts were applied by means of a rotary hand duster at a rate to correspond to 40 to 45 pounds of dusts per acre of sprouts. Mortalities at intervals of from 1 to 6 days are shown in table 1. These tests indicated that it required a five per cent metaldehyde dust to affect slugs when dusted directly, although a two per cent dust gave a fair kill at the five day interval following application. Two and 5 per cent dusts also affected slugs when they were placed on dusted leaves. Although *Milax gagates* were slightly more resistant to the dusts, there was actually little significant difference. For this reason the mortalities in tables 1 and 2 are an average kill for both species.

In field applications applied by grower power dusters during September, 1951, at Half Moon Bay, the 5 per cent metaldehyde dust was more

[1] Associate Entomologist, Davis, and Agriculturist, Half Moon Bay, San Mateo County, respectively.

[2] *Agriolimax agrestis* L. of most authors.

Acknowledgments: The authors express their appreciation to L. R. Gardner and G. S. Hensill of the California Spray Chemical Corporation, and to T. Castle of A. L. Castle, Incorporated, for preparing the dust formulations discussed in this article.

Table 2.—Effect of metaldehyde and parathion dust applications to slugs in cage tests.

Dust Treatment	Per Cent Mortality at Day Intervals Following Exposure[1]					
	1	2	3	4	5	6
Direct application to slugs						
Metaldehyde 3%	0.0	0.0	0.0	0.0	13.3	13.3
Metaldehyde 5%	0.0	0.0	0.0	13.3	46.7	66.7
Metaldehyde 10%	0.0	7.0	13.3	26.7	40.0	66.7
Metaldehyde 5% plus parathion 2%	0.0	0.0	0.0	7.0	60.0	86.7
Check, no treatment	0.0	7.0	13.3	26.7	26.7	26.7
Check, parathion 2%	0.0	0.0	0.0	7.0	7.0	20.0
Application to glass plates on which slugs are placed						
Metaldehyde 3%	0.0	0.0	0.0	7.0	7.0	20.0
Metaldehyde 5%	0.0	0.0	0.0	7.0	7.0	7.0
Metaldehyde 10%	0.0	7.0	7.0	7.0	13.3	13.3
Metaldehyde 5% plus parathion 2%	0.0	0.0	0.0	0.0	13.3	13.3
Check, no treatment	0.0	7.0	7.0	7.0	13.3	13.3
Check, parathion 2%	0.0	7.0	7.0	7.0	13.3	13.3

[1] Mortalities at each time interval refer to per cent dead in relation to total number of slugs caged.

effective in killing slugs than were lower concentrations, and better control was obtained in areas between the plants where slugs were exposed to sunlight during the daytime.

Tests were conducted at Davis during March 1952 to determine the effect of metaldehyde dusts on the same species of slugs if, after exposure to the dusts, they were kept in closed containers at 100 per cent relative humidity. For these tests 10 slugs of each species were placed on clean glass plates, dusted, allowed an exposure period of 9 minutes, then removed to clean blotting paper saturated with water in battery jars with glass lids. Equal numbers with each dust concentration were not dusted directly, but placed on the deposit and allowed to crawl about on the dusted glass for a 9 minute period. The jars were kept in the shade at outdoor Davis temperatures, and examined daily to record mortalities. Dusts were applied at a rate equivalent to 40 pounds of dust per acre of Brussels sprouts. The results shown in table 2 indicate that the 5 and 10 per cent metaldehyde dusts and the 5 per cent metaldehyde with 2 per cent parathion were most effective in killing slugs by direct contact. Due to the fact that the humidity was kept high it took 5 to 6 days after exposure for full effects to be exhibited.

It was also apparent that where the slugs were given only a 9 minute exposure to dusts on glass plates that the metaldehyde dusts were ineffective. Apparently the slugs were able to slough off the dusts and recover.

These preliminary tests indicate that the optimum metaldehyde dust concentration for field slug control is about 5 per cent under these particular conditions. Metaldehyde can apparently be combined with parathion for a combination action against mollusks and aphids. In these combination dust mixtures it might prove desirable to reduce the metaldehyde content to 3 or 4 per cent. A test run after a 1 month storage period of a 5 per cent metaldehyde, 2 per cent parathion mixture indicated that there was no decomposition of parathion. Tests on possible decomposition after longer periods of storage are in progress.

Metaldehyde dusts seem more effective when applied directly to slugs, and at times when the animals are active. The effectiveness is correlated with climate following application. Cool, foggy conditions at the time of application, followed by warmer conditions when the slugs become exposed to dessicatory influences, seem most favorable for control. Relatively heavy applications of 40 to 45 pounds per acre have given better results.

The full effects of metaldehyde on Brussels sprouts have not been determined, and for this reason mixtures containing this chemical, or combinations with other chemicals, should be used with caution until more information is available. There is every indication that dusts containing this chemical do not constitute a serious hazard to health if used properly.

In formulating dust mixtures it was found necessary to prepare a 50 per cent metaldehyde concentrate and blend this with soapstone or other diluents in preparing a final dust. The density and physical nature of the chemical requires this precaution. The chemical is also volatile and this fact should be taken into consideration in placing dusts in bags.

Preliminary tests indicate that metaldehyde dusts may also have some place for mollusk control in greenhouses, about nurseries, or for lawns. These uses will require further investigations.[1]

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[1] Test conducted by Dr. Allen B. Lemmon, State Bureau of Chemistry, Sacramento, California.

The Susceptibility of Two Species of *Colias* to the Same Virus[1]

Edward A. Steinhaus, *University of California, Berkeley*

A few investigators have reported the experimental susceptibility of certain insect species to viruses normally found infecting other species of insects. Nevertheless, the apparent pronounced host specificity of most insect viruses has been one of the prominent characteristics of this group of viral agents. Under ordinary circumstances a virus capable of infecting a particular species of insect has usually appeared incapable of infecting other insects, even closely related species. The purpose of this note is to report the susceptibility of the alfalfa caterpillar, *Colias philodice eurytheme* Boisduval, to the polyhedrosis virus of a South American species of the same genus, *Colias lesbia* (Fabricius).

The virus, *Borrelina bombycis* Paillot, causing jaundice of the silkworm, *Bombyx mori* (Linn.), was claimed by early investigators (*e.g.*, Bolle, see von Prowazek, 1907) to be capable of infecting not only other Lepidoptera, but even a species (*Dermestes lardarius* Linn.) of Coleoptera. There are sufficient reasons for questioning the validity of some of these reports (see Steinhaus, 1949*a*). Glaser (1927) did not find the larva of the tent caterpillar, *Malacosoma americana* (Fabr.), to be susceptible to the silkworm virus (or to that of the caterpillar of the gypsy moth, *Porthetria dispar* (Linn.)). Bergold

[1] Contribution from the Laboratory of Insect Pathology, Division of Biological Control, College of Agriculture, University of California, Berkeley 4, California.

(1948), however, reported that the larvae of *Porthetria dispar*, *Lymantria monacha* Linn., and *Dendrolimus pini* Linn. are experimentally at least, partially susceptible to the virus of silkworm jaundice. Similarly, Bergold states that the larvae of *Porthetria dispar* and *Dendrolimus pini* are partially susceptible to *Borrelina efficiens* Holmes, the cause of Wipfelkrankheit, a polyhedrosis of the larva of the nun moth, *Lymantria monacha*. Silkworm larvae did not appear to be susceptible to the virus of *Lymantria monacha* or to that of *Dendrolimus pini*, but they were to some degree susceptible to *Borrelina reprimens* Holmes, the cause of a polyhedrosis of the gypsy-moth caterpillar, *Porthetria dispar*. Glaser (1927), however, found the silkworm to be resistant to infection by the gypsy-moth virus, as well as to infection by the tent caterpillar virus. Jucci (1944), in discussing his attempts to increase the resistance of *Phylosamia* larvae to polyhedrosis virus, infers that the larvae are susceptible to the virus of *Bombyx mori*.

In our own laboratory, Tanada (data to be published) was able to infect larvae of the imported cabbageworm, *Pieris rapae* (Linn.), with *Borrelina campeoles* Steinhaus, a virus causing a polyhedrosis of the alfalfa caterpillar, *Colias philodice eurytheme* Boisduval. A similar virus found in *Pieris* larvae reared in the same laboratory was, in turn, infectious for the alfalfa caterpiller. When the triturated remains of healthy larvae of *Pieris* were fed to *Colias* and that of *Colias* to *Pieris*, no polyhedrosis developed in the test larvae, thus indicating that the previous infections were probably not the result of "shock" which might have elicited latent virus. The successful cross-infectivity in this case suggests that the virus found in each of the host insects may be the same, although the possibility exists that the viruses are different but equally capable of infecting the two host species. Tanada also observed that the cabbageworm was not susceptible to the polyhedrosis viruses known to infect the beet armyworm, *Laphygma exigua* (Hbn.); the western yellow-striped armyworm, *Prodenia praefica* Grote; and the California oakworm, *Phryganidia californica* Pack. Furthermore, the cabbageworm virus is not infectious for *Laphygma* and *Phryganidia* larvae.

In October, 1951, Ing°. Agr°. Juan Carlos Nicolini, in a personal communication, informed the writer that a polyhedrosis of *Colias lesbia* (Fabr.) had been observed in Argentina by Ing°. Mario Griot. This observation was made in 1939 and in the years following. Epizootics of the disease in the caterpillars of this insect presented the classical characteristics of such outbreaks of polyhedrosis in large populations of insects.

It occurred to us that the known presence of a polyhedrosis in the Argentine *Colias* provided an opportunity to determine its intra-generic host specificity by testing its infectivity for our western North American species (*Colias philodice eurytheme* Boisduval). Accordingly we requested Ing°. Nicolini to send us larvae of *Colias lesbia* killed by the polyhedrosis. This he kindly agreed to do, and such specimens were received by us in early March, 1952.

That the larvae of *Colias lesbia* received from Argentina were infected with a polyhedrosis virus was readily confirmed by electron microscope examinations. The polyhedra and virus particles seen in preparations from *Colias lesbia* were in all essential respects similar to those from *Colias philodice eurytheme* which has been described in some detail elsewhere (Steinhaus, 1948, 1949*b*).

To ascertain whether or not *Colias philodice eurytheme* is susceptible to the virus found in *Colias lesbia*, the following infectivity experiment was set up: 43 third-instar larvae of *C. philodice eurytheme* were placed in individual, sterile, cardboard containers covered with a petri-dish half. Sprigs of alfalfa, with stems placed in a cotton-stoppered vial containing water, were used as food. Of the 43 caterpillars, 25 were used as test insects and 18 were used as untreated controls. The food of the 25 test larvae was immersed briefly in an aqueous suspension of the Argentine virus prepared from the dead larvae of *Colias lesbia*. A small amount of blood albumen was added to the suspension to facilitate its spread over the leaves of the food plant.

Of the 25 test larvae, 21 died of polyhedrosis as determined by light microscope examinations of the body contents of the dead insects. The remaining four eventually may have succumbed to the polyhedrosis, had not their death by intercurrent bacterial infections intervened. Two of the 18 control larvae died during the course of the experiment from amicrobial causes; the remaining 16 survived through the larval stage and pupated with no signs of infection of any kind. In a second experiment these results were confirmed when 31 out of 32 of our alfalfa caterpillars died of polyhedrosis after being fed the Argentine virus, while the controls remained disease-free. The results of other experiments being run in our laboratory indicated that the infectivity obtained here was not the result of "shock" or other stimulation that might prompt the elicitation of latent virus.

In a third experiment, four lots of caterpillars of *Colias philodice eurytheme* were given food: (1) immersed in a suspension of the Argentine virus; (2) immersed in a suspension of the North American virus (*Borrelina campeoles*); (3) immersed in sterile water; and (4) untreated. Each of the four lots consisted of 10 third-instar larvae. None of the larvae in the control lots (3 and 4) died of virus infection. Of the 10 caterpillars fed the Argentine virus, all 10 died of polyhedrosis. A similar result was obtained in the case of the 10 caterpillars fed the North American virus.

The results of these preliminary experiments show that larvae of *Colias philodice eurytheme* Bdvl. are susceptible to a polyhedrosis virus occurring in *Colias lesbia* (Fabr.). Thus, there is an indication that within the genus *Colias* the polyhedrosis virus naturally infecting one species of caterpillar is capable of infecting another species. From a phylogenetic standpoint these species apparently need not be closely related, as is denoted by the fact that within the genus *Colias*, *C. lesbia* belongs to the *Crocea* Group whereas *C. philodice eurytheme* belongs to the *Hyale* Group. It seems probable that the Argentine virus is the same virus (*Borrelina campeoles*) that is found in North American alfalfa caterpillar, but the experiments reported here do not, in themselves, prove that such is the case.

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Effects of Insecticidal Dusts Containing Piperonyl Butoxide and Pyrethrins Applied to Wheat on the Flavor of Eggs[1]

DONALD A. WILBUR[2]

During laboratory and field studies in which protective dusts containing piperonyl butoxide and pyrethrins were applied to wheat to prevent damage by grain infesting insects, it was noted that a mild odor was imparted to the wheat that persisted for several days. The odor however was not sufficient to cause the wheat to be graded down by official grain graders.

Eggs are quick to reflect off-flavors and odors found in the food consumed by laying hens, and farmers frequently feed their stored wheat to poultry as scratch feed. Accordingly, a test was planned to determine if protectant dusts applied to wheat at four times the recommended strength, and the wheat fed to laying hens as their only source of scratch feed, would impart an undesirable odor or taste to the eggs.

The dust formula being tested was supplied by the U.S. Industrial Chemicals Co. and consisted of 0.8 per cent piperonyl butoxide and 0.05 per cent pyrethrins impregnated in pulverized wheat. The material is known commercially as pyrenone wheat protectant. The protectant was thoroughly mixed with the wheat at the rate of 400 pounds per thousand bushels of wheat.

The treated wheat was fed to a laying flock of white leghorns at the Kansas State College poultry farm as their only source of scratch feed. The feeding was done between 8 and 9 o'clock each morning from April 14 until April 21, 1951. Approximately 0.1 pound of wheat was used per hen per day during this period. An equal amount of mash was used.

The eggs produced, up to a maximum of 12, were collected on each of the following dates: April 17, 19, and 21. The eggs were promptly placed in a refrigerator in the Department of Foods and Nutrition where they were held until the end of the feeding period.

On April 23, cooks prepared eggs from each lot by cooking them in hot water to the hard-cooked stage, after which the eggs were tasted by a taste panel of six members.

RESULTS.—The hens accepted without noticeable difficulty the wheat which had been heavily treated with the protectant dust. Each day's allotment of treated wheat was cleaned up promptly.

There was no significant change in the egg production of the flock. The egg-laying record of the flock was as follows:

Week ending April 15—160 eggs
April 22—147 eggs
April 29—171 eggs
May 6—147 eggs

A report from Dr. Gladys Vail, head of the Department of Foods and Nutrition, who assumed responsibility for the preparation of the eggs for taste and for organizing the taste panel, included the following statement:

> "Six members of the palatability committee were present when the eggs were done. Two persons working together broke the eggs, one from each lot, and smelled them immediately. The eggs were then tasted while warm, almost hot. No member of the group of six was able to detect any off odor or taste in any one of the eggs. We therefore concluded that as a result of the feed the hens had deposited no foreign material in the eggs which could be detected by the consumer."

It was originally intended to include a test to determine if flavors would be imparted to the flesh of chickens. But since no trace of flavors could be detected in the eggs, further tests were deemed unnecessary.

[1] Contribution No. 595 Department of Entomology. Studies conducted at the Kansas Agricultural Experiment Station Commercial Project No. 94 using grant-in-aid funds provided by the U. S. Industrial Chemicals Co.; The Departments of Entomology, Poultry, and Foods and Nutrition cooperating.

[2] Professor of Entomology, Kansas State College, Manhattan, Kansas.

NEW BEPQ DIVISION ESTABLISHED

Avery S. Hoyt, chief of the Bureau, announced on April 10, 1952 that a Division of Bee Culture and Biological Control had been established in the Bureau of Entomology and Plant Quarantine. The new Division will be responsible for research relating to the biological control of insect pests and weeds, and diseases of insects. All the Bureau's activities in connection with bees and beneficial insects are to be consolidated into this Division. James I. Hambleton, former head of the Division of Bee Culture for 30 years is in charge of the new Division. Willis J. Nolan, formerly Hambleton's first assistant, will be in charge of the Section of Bee Culture Research, and Theodore R. Gardner will head the Section of Biological Control.

PAUL A. HOIDALE RETIRES

After 36 years of service, Paul A. Hoidale, retired from the BEPQ on May 1, 1952. Mr. Hoidale first joined the U. S. Department of Agriculture in 1915 and worked on citrus canker investigations. From 1917 to 1927 he was on pink bollworm control work in Texas for the Federal Horticultural Board. Citrus black fly surveys in Mexico and Mediterranean fruit fly eradication work in Florida then engaged his attention. From 1927 to 1950 he was in charge of the Bureau's fight against the Mexican fruit fly in the lower Rio Grande Valley of Texas. Since 1950 he had been in charge of the grasshopper control work with headquarters at Minneapolis, Minn. Mr. Hoidale has returned to Texas and is living at 821 Bowie Street, Harlingen.

EDITORIAL

Forest Entomologist—Forester or Entomologist?

Usually the classification of fields of activity is easy. A forester is a man whose work contributes to the management of forest lands. An entomologist is one who works with insects. These distinctions seem clear enough. But what is this individual who calls himself a forest entomologist; who goes into the woods to evaluate condi, tions and who dispenses recommendations on what to do about various forest insect situations? The answer to this question also seems clear to some of us. Since he satisfies the requirements of both definitions, he is *both* a forester and an entomologist. To be effective he must understand at least the basic principles in both fields. Nevertheless, if we are to judge by what students are taught in various courses entitled Forest Entomology, and what many who are headed toward specialization in this field fail to learn about the forest and forestry, we must conclude that some teachers might not agree with this answer.

Some courses called Forest Entomology consist chiefly of a battery of life histories and descriptions of each insect's appearance. Some emphasize taxonomic relations, some play up ecological phenomena, and some combine these various ingredients in different proportions with a sprinkling of control techniques added.

A certain amount of variation between courses and programs of study in forest entomology is not only inevitable, but desirable. Stereotyped training is never to be encouraged. However, many young foresters, having failed to see how entomology and forestry fit together, leave school with a warped idea as to what forest entomology really is. Even though they may have emphasized the study of forest entomology while in school, they still may be poorly equipped to solve forest insect problems either as young foresters or forest entomologists. Therefore, it seems important that certain facts should be recognized to guide teachers in planning courses and programs of study.

In this paper we are considering the training of two different groups. First those students who will later become specialized forest entomologists and secondly those who will, as foresters, put the recommendations of specialists into effect. These are the men for whom programs in forest entomology should be designed. Their training is most often on the Master level. We are not immediately concerned with the training of highly specialized men who may deal with some restricted phase of forest entomology: taxonomy, biology, or various direct control procedures including chemical treatments, or who will deal with the more complex aspects of ecology. These specialists are likely to be concerned with research and will usually be developed on the doctoral level. Their background training may vary greatly.

Although our programs in Forest Entomology need not be identical, nevertheless they should provide the forester with an intelligent understanding of the insect problems that he will inevitably meet in managing timber lands, and the young forest entomologist with a sound foundation that will make it possible for him to carry on effectively the work which he will be expected to do on graduation. In order to accomplish these two objectives we must coordinate our courses in forest entomology with the forestry program for the benefit of the forester on the one hand, and the forest entomologist on the other. There was a time when a man trained only in entomology could be an effective forest entomologist; but not today. Forest entomology must keep pace with forest practice.

Forest practices during the past 30 to 40 years have been changing rapidly. From programs of exploitation without regard to the future, most of the larger forest operators have accepted sustained yield management of their timerblands as a matter of course. Under a system of exploitation the forest entomologist was expected only to protect the timber until it could be used. Under a system of sustained production he is expected to protect the growing forest from insect devastation for an indefinite period. Furthermore, he is expected to accomplish control by means that are economically

practicable. Thus, forest entomology is becoming more and more an integral part of forest practice and the forest entomologist is expected to know more and more about the techniques that are used in growing and utilizing trees. Courses in forest entomology, therefore, must be adjusted to meet these changed conditions.

Along with improved forest practices has come an increasing realization that insect-caused damage must be checked. Outbreaks of barkbeetles and defoliating insects have in the past so alarmed forest operators that they have often felt obliged to liquidate their timber investments as rapidly as practicable. Recently, however, the possibilities of spraying forests from the air and the development of improved preventive techniques for bark beetle and defoliator control have changed this attitude.

The need for prompt apprehension of dangerous situations so that remedial measures can be applied promptly is now generally appreciated. The result has been a growing emphasis on annual surveys for evaluation of forest insect conditions. Thus incipient outbreaks may be detected, the need for control determined, and control measures applied before serious damage has occurred. The trained men needed for these surveys exceed the number available. Therefore, the young forest entomologist on his first job, except for those few who will be employed on research projects, is likely to be engaged in survey work.

The forest entomological neophyte may be surprised to discover that the tools of his trade will be the compass, the axe, the increment borer, the diameter tape, and the tally sheet more often than the microscope or the pinning forceps. If he cannot use these common tools of the forester, many jobs in forest entomology will be closed to him. In his work he will be expected to evaluate insect conditions in the forest and report intelligently to his superior. Later when he has demonstrated sufficient competence and judgment he will be expected to advise forest managers on practical problems concerning forest insects and to direct various operations.

Since we shall probably be short handed on the surveys for some time to come, foresters without any special training beyond an elementary course in forest entomology will often be called on to assist in this work. The general course in forest entomology should therefore include instruction concerning survey procedures. Also the forest manager should know enough about forest entomology to recognize the existence of an insect problem before things get out of hand. Furthermore, becuase silvicultural practices may either increase or decrease the danger of insect outbreaks, he should receive instruction in silvicultural as well as other preventive practices. From this we see that instruction in forest entomology is a two-edged sword that should be coordinated with the forest production program to provide the general forester with an intelligent conception of forest insect problems, and the forest entomologist with a foundation for further training.

Clearly, the student who expects to become a forest entomologist cannot confine his attention entirely to those things that are taught in entomology departments. He must, in addition, have training in the techniques of forest production. Whether the courses in forest entomology are handled in a department of entomology or taught in a school of forestry, this coordination is equally important. It is, therefore, high time that every teacher of forest entomology should scrutinize the content of his courses and determine whether or not they meet the modern needs. To do this teachers of forest entomology must themselves become familiar with forest practices just as teachers in other branches of economic entomology must become familiar with farm, orchard, or industrial practices.

Assuming that this coordination is to be accomplished and that the young forest entomologist is to have adequate training in both forest production and entomology, what should be included in his program of study to fit him to do those things which his employers have a right to expect him to do on graduation? Naturally, these requirements may be fitted together in various ways. The program will involve a number of courses and may cut across departmental lines. Sometimes one phase may be emphasized more and sometimes less, but it seems very clear that a young forester or the beginning forest entomologist should have a reasonable knowledge of the following:

(1) He should be able to recognize the

commoner insect species that cause serious injury in the locality where he will be working. No single course can be expected to provide a student with a knowledge of all dangerous species in every locality where he might go. He should, however, be able to recognize the common orders and families and representative widely-distributed species of tree insects. With this background, he will be able to learn quickly for himself the species which he is most likely to encounter in the particular locality where he finds employment.

(2) He should know the life history and habits of representative noxious species in the various ecological groups. With this basic knowledge, he can from literature learn about his local species.

(3) He should receive instruction and have opportunity to practice in the use of forest entomological literature.

(4) He must learn what forest types are particularly subject to injury by various insects and in which types injury is not likely to occur. This knowledge will permit him to forecast probable trends when an incipient outbreak appears and will help him to judge when direct control measures are necessary. Also, on the basis of this information he will frequently be able to suggest silvicultural practices which will materially reduce the danger of insect outbreaks.

(5) He must know what control practices, both direct and indirect, may be used to check pests. In this connection he must understand the values involved, both the cost of control and the value of the products that will be protected. The basic principles that must be considered in determining whether or not control measures are justifiable should be included in college courses, but the judgment required to apply these principles can only be gained by experience.

(6) He must learn the techniques of evaluating insect populations. In order to do this he must understand the principles of sampling and the techniques required to evaluate the accuracy of the samples. This knowledge may be gained in various ways; perhaps in forest mensuration or perhaps in statistics courses.

(7) He must be taught the various methods used in making forest insect surveys. These surveys must inevitably be quantitative and the results comparable from year to year. To make this possible, observations must be made systematically and in the same manner season after season. This is an especially important part of the forest entomologist training since the first job of the young graduate is likely to be on survey work. In this connection he will also need to know the basic principles of timber cruising.

(8) In order to understand the increase or decline of insect populations, it is necessary that he should understand the forces of production and destruction that determine whether a population will increase, decrease, or remain stationary. He should understand the significance of the forces of reproductive potential and environmental resistance and he should know how the various factors of environmental resistance can be measured. Training along these lines is difficult to obtain outside the classroom and should be a part of every program in forest entomology.

(9) The legal basis for forest insect control, both local and national, should not be overlooked. The young forest entomologist should know about the various acts of Congress leading, in 1947, to the adoption of the Forest Pest Control Act. He also should know under what legislative and the legal authority control operations on both public and private lands may be instituted. Legislative action restricting the movement of infested materials within states, between states, and in international trade should be a part of the training of the young man who will be concerned with forest insect problems. It is far easier to learn these things in school than to be embarrassed by ignorance later.

(10) And last but by no means least, he must learn how to locate himself in reference to the land survey, an accomplishment that requires both training and practice.

A young man whose training includes these ten essentials will be in a position to meet the requirements expected of the beginner in forest entomological work. Lacking any one of them he will be handicapped. With them he will not only be equipped for an immediate job but he will also be prepared for further specialized training.

SAMUEL A. GRAHAM

OBITUARY

Traber Norman Dobbins

1896-1952

The sudden death from a heart attack of Traber Norman Dobbins at his home in Moorestown, N. J. on April 14, 1952, came as a shock to his friends and associates, ending almost 20 years of continuous service in the Bureau of Entomology and Plant Quarantine. He was buried with military honors in the National Cemetery at Beverly, N. J.

Traber Norman Dobbins was born at Las Animas, Colorado, on November 25, 1896. He received a medical certificate from the University of Mississippi in May 1924, his B.S. degree from Mississippi State College in May 1927, and his M.S. degree from the Agricultural and Mechanical College of Texas in May 1932, having completed courses in entomology, bacteriology, pathology, physiology, chemistry and physics.

He was an instructor in biology and English at the Oktibbeha Agricultural High School, Longview, Miss. from September 1927 to May 1928, and an instructor in biology, English and music at the Sunflower County Junior College, Moorehead, Miss. from September 1928 to May 1931.

He was appointed field aid in the Division of Fruit Insect Investigations, Bureau of Entomology and Plant Quarantine, in 1932 and was assigned to the Japanese Beetle Laboratory, Moorestown, N. J. He was promoted progressively and received an appointment as entomologist in 1940. While at the Japanese Beetle Laboratory, Mr. Dobbins assisted the late Dr. Henry Fox and Dr. Ira M. Hawley in studies of the biology of the Japanese beetle, and later he assisted Dr. S. R. Dutky in investigations of diseases of the beetle. October 20, 1946, he was transferred to the Division of Cereal and Forage Insect Investigations at Beltsville, Md., where he assisted in investigations on the control of alfalfa, red clover, and peanut insects and conscientiously contributed to the insecticide residue studies connected therewith.

Mr. Dobbins was married to Vera D. Pruitt at Meridian, Miss. on June 4, 1926. He is survived by his wife and the following children: Robert Norman, Carolyn and Beverly.

He was an accomplished musician, playing the clarinet, saxophone and other wind instruments. He enlisted in the Navy in March 1918 and served as a musician, 2nd class in the Naval Band at the Naval Hospital, Ft. Lyon, Colo. until his discharge in February 1919. While at Mississippi State College, Mr. Dobbins played in the college band, and more recently, he played in local bands in Palmyra, N. J., Burlington, N. J., and in Laurel, Md. While at Sunflower County Junior College, he was instructor for the band, orchestra and glee club.

Mr. Dobbins was interested in all wild life, particularly birds and wild flowers, and thoroughly enjoyed outdoor activities. He was also an enthusiastic fan of high school and other sports—football, hockey, basketball, bowling, etc. He was a member of the American Association of Economic Entomologists, Entomological Society of Washington and for many years the Entomological Society of America, and of Trinity Episcopal Church of Moorestown, N. J.

W. E. Fleming
Harry W. Allen
F. W. Poos

BOOK NOTICE

Ground Equipment and Insecticides for Mosquito Control, Bul. No. 2, American Mosquito Control Association, Inc., Yaphank, New York, 116 pages, illustrated. Edited by E. F. Knipling, 1952.

During World War II and the period following it, many new and efficient insecticides and a wide variety of equipment for their application were developed. This resulted in a rapid accumulation of much valuable knowledge which needed to be brought together in concise form for use by mosquito control workers. This has been undertaken by the American Mosquito Control Association through a special committee which prepared this bulletin.

The bulletin is designed to provide mosquito workers, manufacturers, distributors and others who might be interested in mosquito control operations with concise information on the kinds of insecticides and ground equipment, as well as the principles involved in their use.

The general principles involved in the use of fog, mist, dust, aerosol and the other more conventional types of equipment are described and illustrated. The places and conditions under which they can best be used in mosquito work are also outlined. The many insecticides and formulations used for mosquito control and factors to consider in their use are discussed. Excellent tables are provided to give the operator information on formulations, dosages and suitable equipment for their application under a variety of conditions and situations.

There is an appendix which provides much useful information on sources of supply for the insecticides and equipment discussed, as well as a series of tables for preparing insecticide dosages for use in the different applicators.

The material in the publication has been assembled from many authentic sources such as the U. S. Public Health Service, the Fish and Wild Life Service, the U. S. Department of Agriculture, State Experiment Stations and the American Mosquito Control Association.

There is a section on precautions outlining how best to use the several insecticides and different types of equipment so as to protect man and animals and minimize the harmful effects on wildlife, beneficial insects and plants.

This booklet will be found useful to anyone interested in mosquito control work.

G. S. Langford

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